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ADVANCED PRODUCTION ENGINEERING (APE) NIGHT VISION SIGHT INFRAR--ETC(U)
DEC 75 DAAK02-73-C-0047
UNCLASSIFIED GSDR-817A-VOL-1 NL

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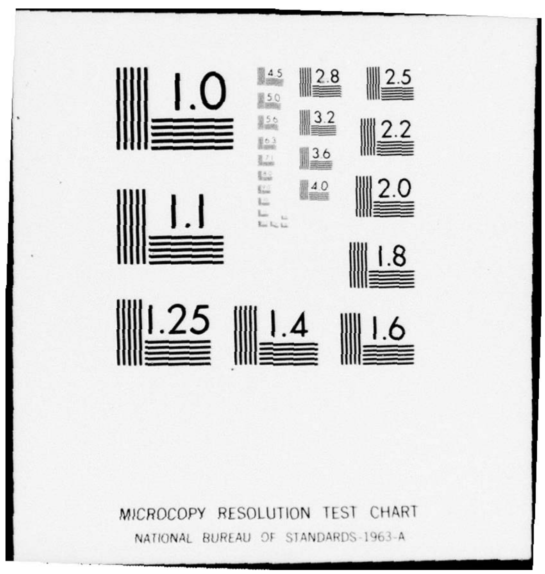
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MICROCOPY RESOLUTION TEST CHART
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12

FINAL REPORT

6 ADVANCED PRODUCTION ENGINEERING (APE)
NIGHT VISION SIGHT INFRARED, AN/TAS-3().
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A NORTH AMERICAN PHILIPS COMPANY

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VOLUME 1

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(Cont.)

SECTION I

INTRODUCTION

1.1 GENERAL

Philips Audio Video Systems Corp., Government Systems Division (PAVSC/GSD) has completed Advanced Production Engineering (APE) for the DRAGON Night Vision Sight AN/TAS-3.

The AN/TAS-3 is a lightweight, battery powered, passive infrared imaging system which is used with the Guided Missile System, Surface Attack M47 (DRAGON). AN/TAS-3 enables the DRAGON gunner to search, detect, recognize and aim at targets during hours of darkness and to accurately track the target during flight of the DRAGON missile. The AN/TAS-3 is shown in Figure 1-1. Figure 1-2 is an exploded view and listing of major subassemblies.

This Final Report is submitted in accordance with the requirements of Contract No. DAAK02-73-C-0047, Contract Data Requirements List No. A022.

1.2 OTHER DOCUMENTS

Other documents associated with the APE and ED programs for the AN/TAS-3 include the following:

- PAVSC/GSD - GSDR No. 815, June 12, 1975, Production Plan.
- DL649069 Data List, Night Vision Sight, Infrared, AN/TAS-3( ).
- SM-D-649070 Assembly Drawing, Night Vision Sight, Infrared AN/TAS-3( ).

  NOTE: The following documents are applicable to the "ED" model AN/TAS-3 only.

- DTM11-5855-241-10, Operators Manual for Night Vision Sight, Infrared, AN/TAS-3( ).
- DTM11-5855-241-20, Organizational Maintenance Manual for Night Vision Sight, Infrared, AN/TAS-3( ).
- PAVSC/GSD GSDR No. 639, Technical Manual for Night Vision Sight, Infrared, AN/TAS-3( ).
- PAVSC/GSD GSDR No. 805A, Final Report for Night Vision Sight, Infrared AN/TAS-3 (ED Model)

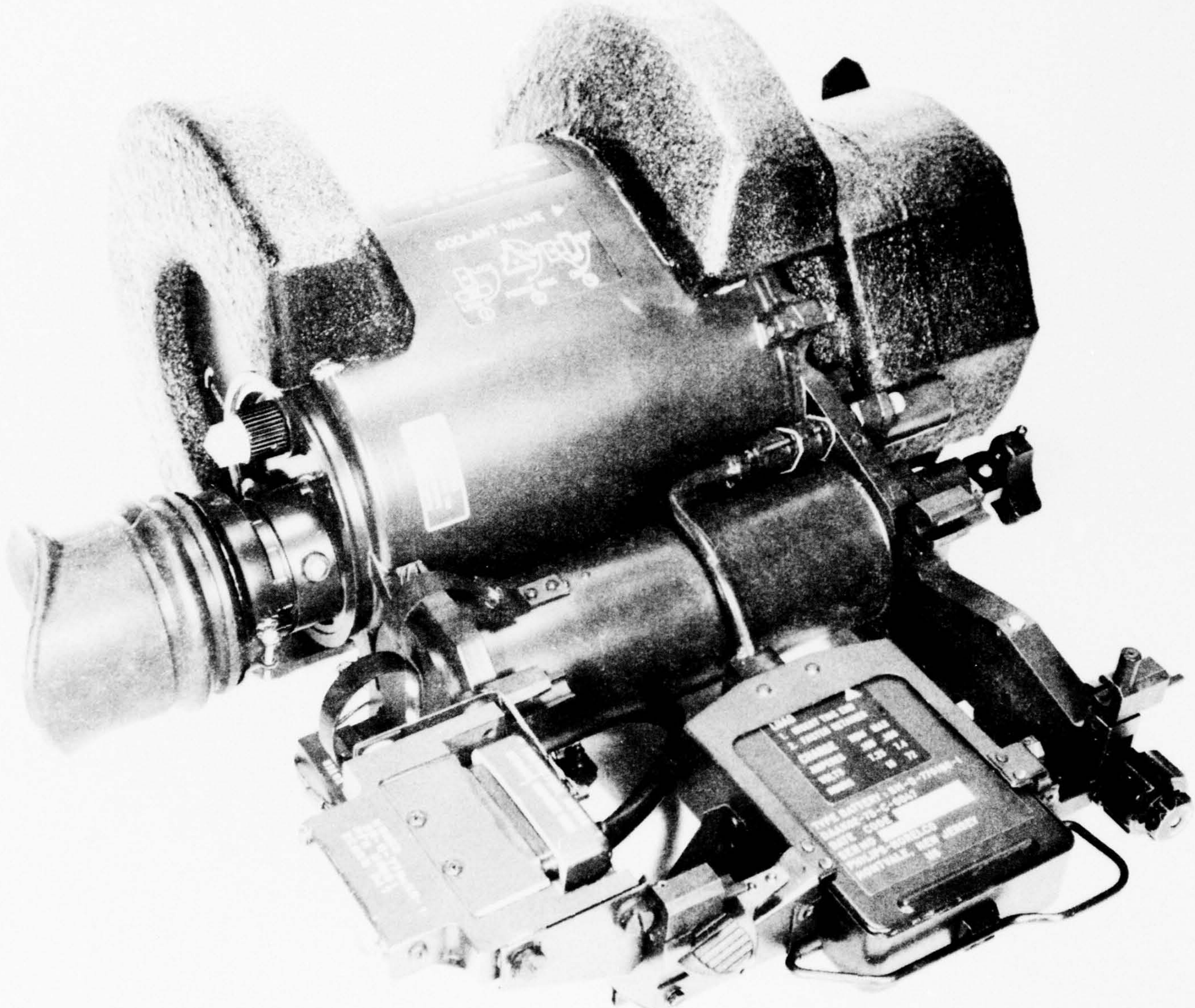
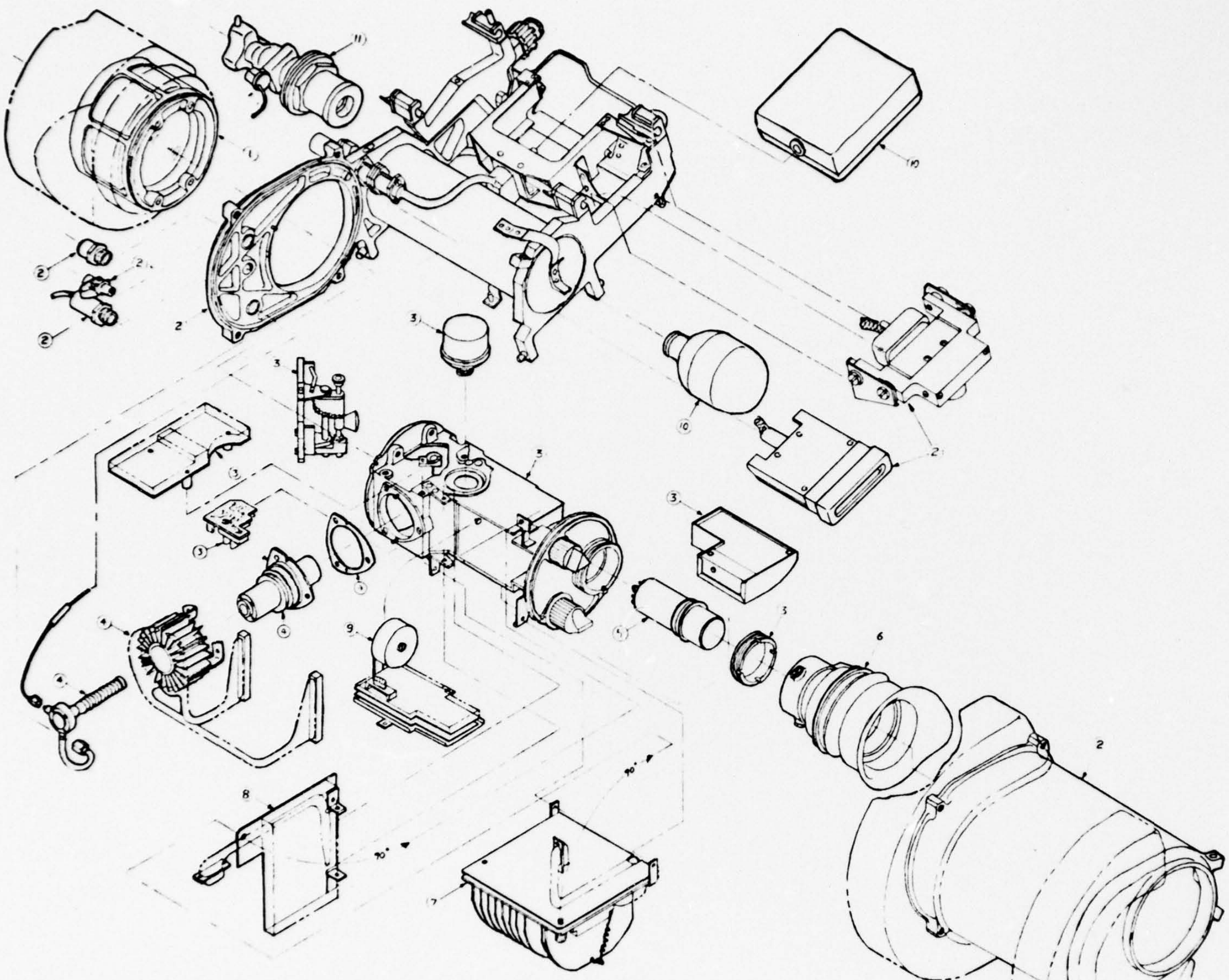


Figure 1-1. Night Vision Sight, Infrared AN/TAS-3 (APE Model)



LEGEND			
1. OBJECTIVE LENS ASSEMBLY	SM-D-770172	8. DISPLAY ELECTRONICS ASSEMBLY	SM-D-649106
2. MAIN FRAME ASSEMBLY	SM-D-770173	9. POWER SUPPLY ASSEMBLY	SM-D-770179
3. SCANNER ASSEMBLY	SM-D-770174	10. BATTERY & HOUSING ASSEMBLY	SM-D-770180
4. DETECTOR COOLER AND BIAS ASSEMBLY	SM-D-770196	11. VALVE ASSEMBLY	SM-D-649251
5. CATHODE RAY TUBE	SM-D-649126	12. CARTRIDGE ASSEMBLY	SM-D-770178
6. EYEPIECE ASSEMBLY	SM-D-649076		
7. PREAMPLIFIER MULTI-PLEXER ASSEMBLY	SM-D-649077		

NIGHT VISION SIGHT, INTERFACE OF ASSEMBLIES

Figure 1-2. AN/TAS-3 Major Subassemblies

1.3 PURPOSE OF PROGRAM

Requirements for this program were to producibility engineer the Engineering Development (ED) Model of the AN/TAS-3 and to establish a pilot production line. In addition, technical data, Special Acceptance Inspection Equipment (SAIE), manufacturing methods and production tooling were to be developed. The primary purpose was to minimize the lead time between the ED phase and production deliveries.

SECTION II

PRODUCTION ENGINEERING

2.1 PRODUCIBILITY

During the APE program the entire design of the AN/TAS-3 was reviewed for producibility to determine what changes or modifications could be made to enable production of the AN/TAS-3 at minimum cost. The results of this review are discussed in paragraphs 2.1.1 and 2.1.2 which cover the electronic and mechanical designs.

2.1.1 PRODUCIBILITY, ELECTRONIC DESIGN

Early in the program a review of the electronics design indicated a number of areas where the major electronic producibility effort was to be concentrated. Included were the low voltage power supply, boresight pulse generator, high voltage power supply and the bias network assembly. These and other assemblies are discussed in the following paragraphs.

2.1.1.1 Low Voltage Power Supply, SM-D-770179

The Low Voltage Power Supply (LVPS), being one of the AN/TAS-3 subassemblies with a relatively high assembly labor content, was selected for a major producibility effort. The LVPS circuit was similar to the circuit being used in the Handheld Viewer (HHV) AN/PAS-7 which had been previously hybridized. Therefore it was decided to incorporate the HHV hybrid into the AN/TAS-3. A specification control Drawing SM-A-770528 was developed for the hybrid and a prototype module, SM-D-770179 was fabricated. This prototype module was subsequently tested over the full operating temperature range of the AN/TAS-3. Results of the test were successful and the module was released as part of the AN/TAS-3 APE model.

The affect of incorporating the hybrid can readily be seen in Figure 2-1 and 2-2 which compares the "APE" printed circuit assemblies with the original "ED" versions. The "ED" LVPS required 96 electronic components which was reduced to 34 in the "APE" hybrid version, a reduction of 64 percent.

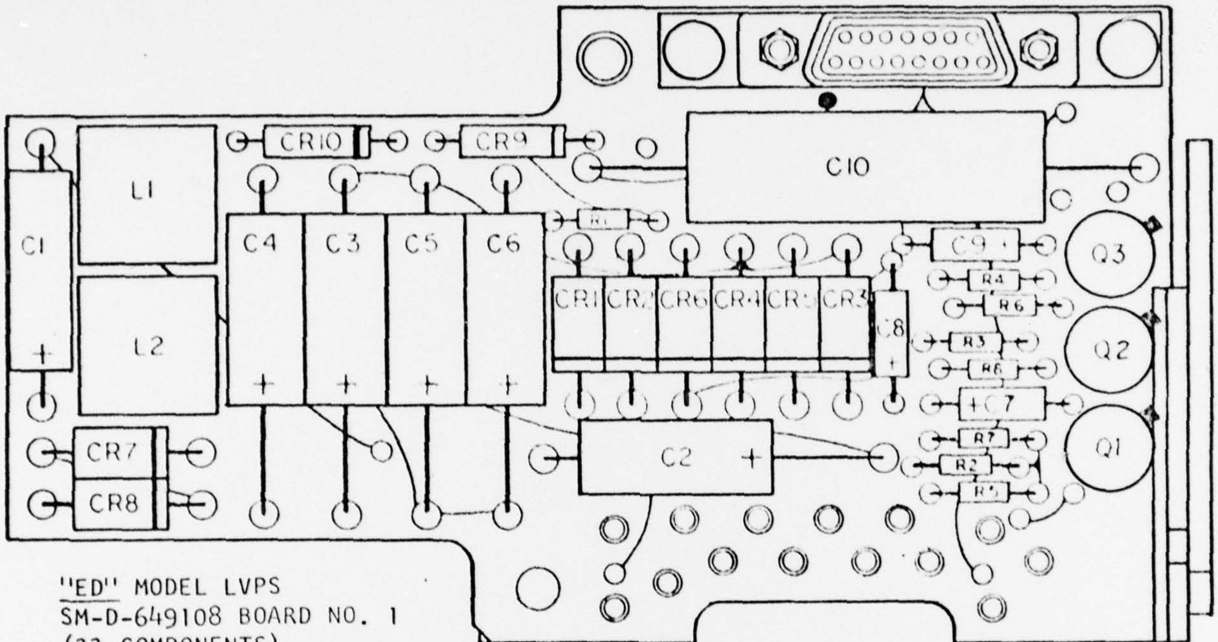
Other improvements to simplify assembly and test were also included. Hinges required to provide access to he module and separation between Board No. 1 and Board No. 2 on the "ED" module were eliminated by designing the module so that it can be completely removed from the scanner housing. In addition, Board No. 1 and Board No. 2 in the "APE" model are designed to "plug together" as compared to being "wired together" on the ED model.

2.1.1.2 Boresight Pulse Generator SM-D-770221

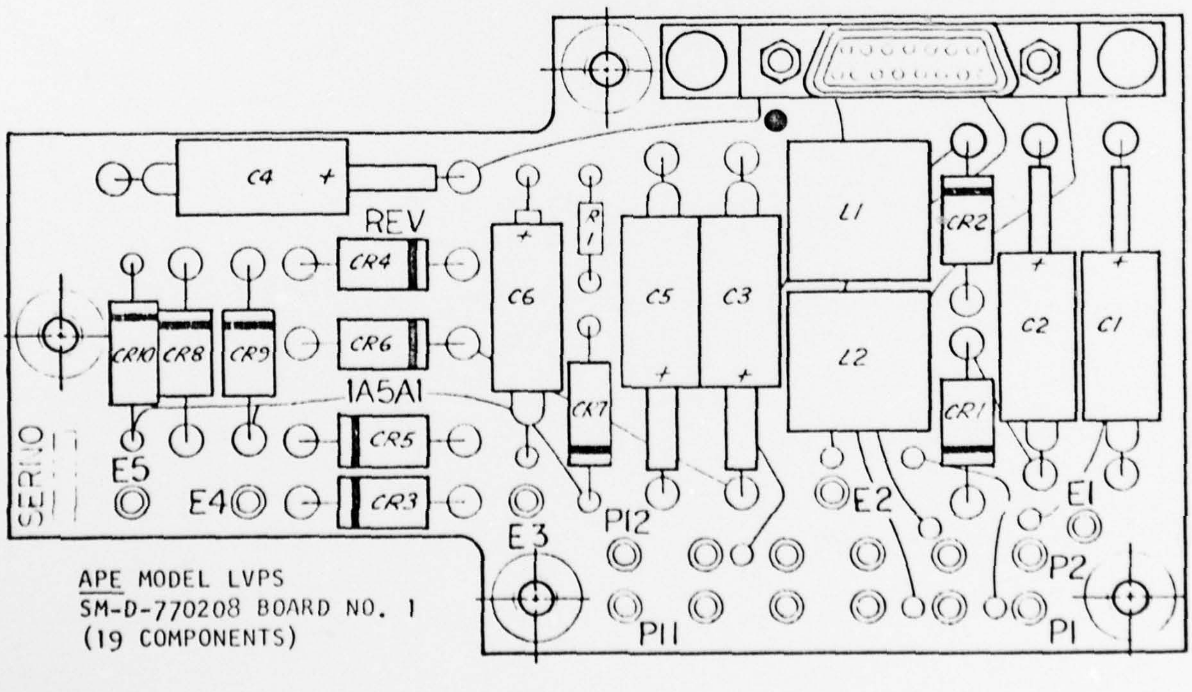
Figure 2-3 illustrates the APE model Boresight Pulse Generator SM-C-770221 which replaced the ED model Angular Position Detector SM-C-649081. This producibility change enabled a single IC amplifier to replace a 14 component, potted cordwood type module, as illustrared in Figure 2-4. Additionally, a simple LED Photo transistor detector, SM-A-770464, replaced a 16 piece electro-optical detector, refer to Figure 2-5. This change eliminated lengthy alignment and assembly procedures while yielding improved reliability.

2.1.1.3 Bias Network Assembly

The total bias network for the 64 element AN/TAS-3 detector consists of 21 SM-D-649101 and one SM-D-649107 printed circuit assemblies. These PC assemblies contain the 64 discrete biasing resistors for the detector. The assembly labor required for this subassembly is higher than any other subassembly within the AN/TAS-3. Therefore a major effort was begun in an attempt to simplify this unit. The evolved plan was to produce a hybrid resistor package and a hybrid FET package.



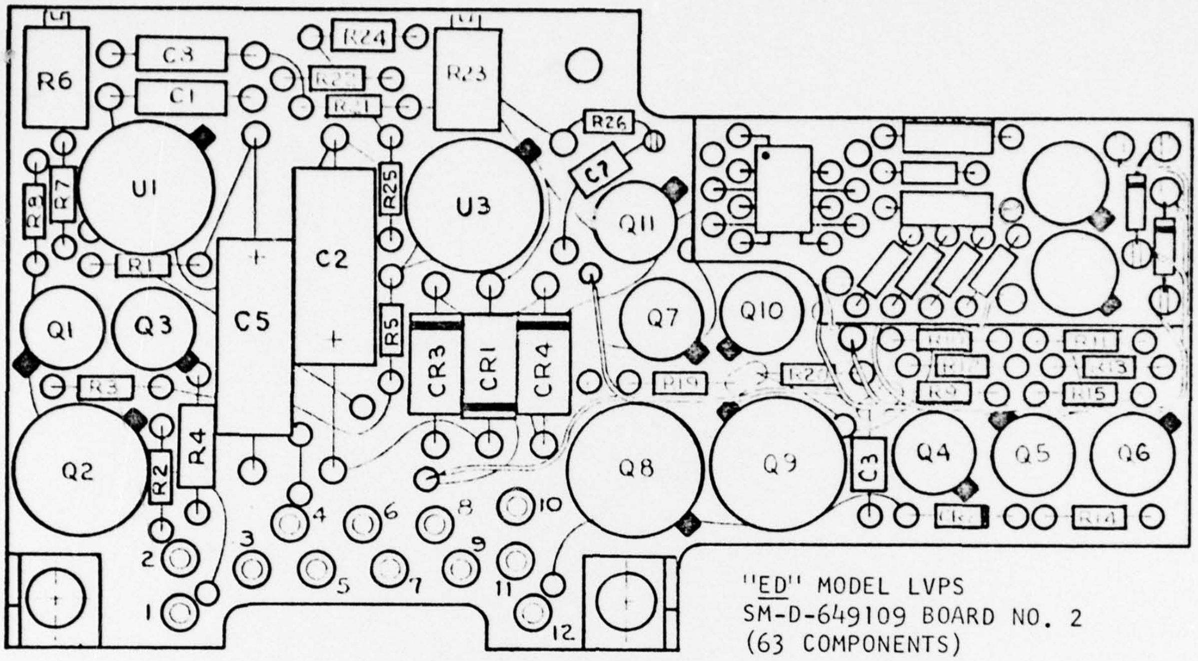
"ED" MODEL LVPS
SM-D-649108 BOARD NO. 1
(33 COMPONENTS)



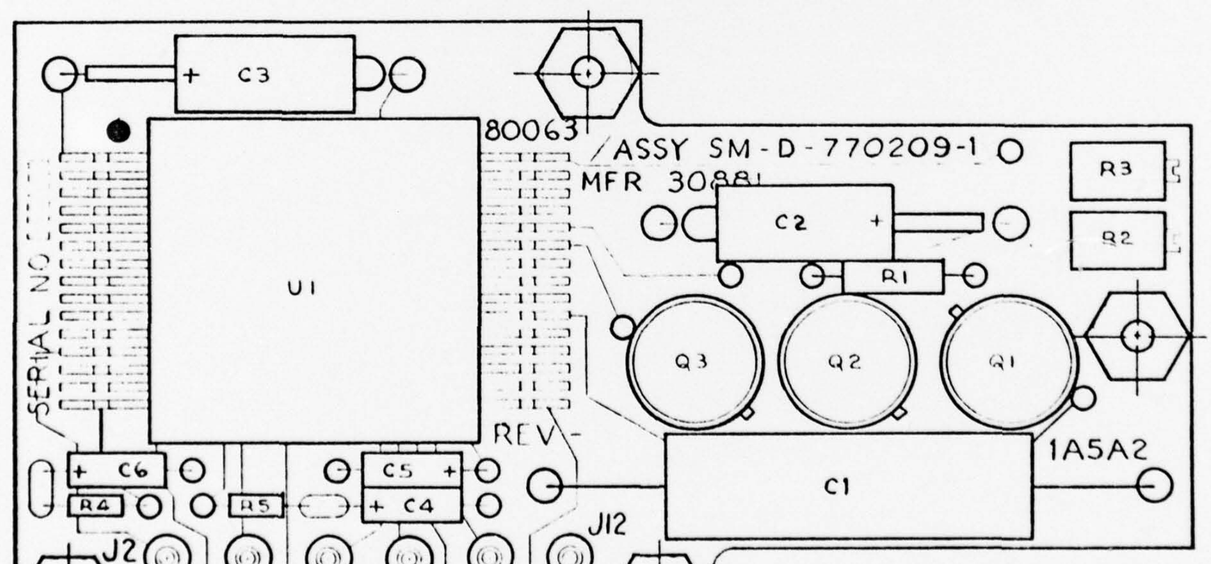
APE MODEL LVPS
SM-D-770208 BOARD NO. 1
(19 COMPONENTS)

Figure 2-1

TP2418



"ED" MODEL LVPS
SM-D-649109 BOARD NO. 2
(63 COMPONENTS)



"APE" MODEL LVPS
SM-D-770209 BOARD NO. 2
(15 COMPONENTS)

TP2419

Figure 2-2

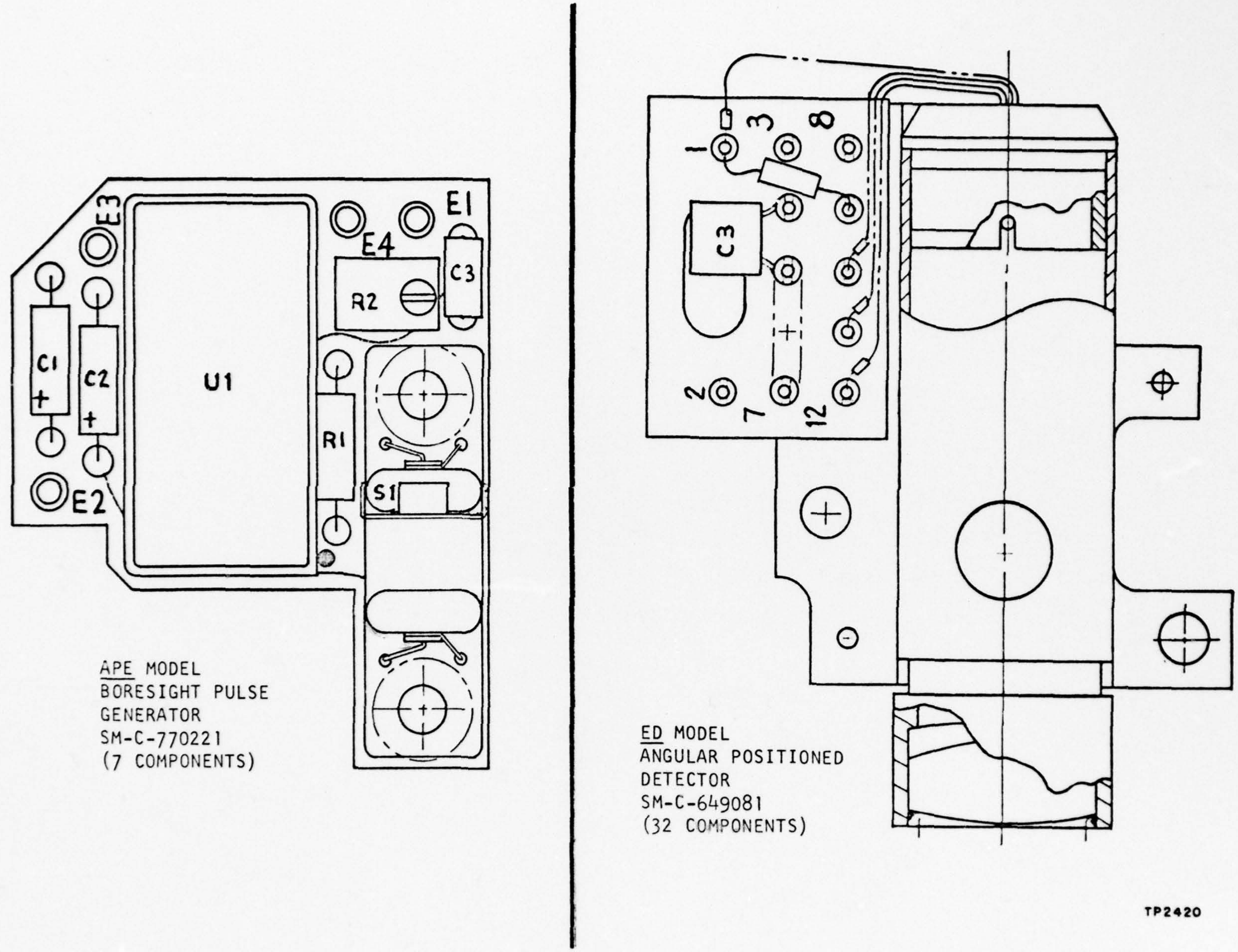

E3
E1
E4
C3
R2
C1
C2
U1
R1
S1
E2
APE MODEL
BORESIGHT PULSE
GENERATOR
SM-C-770221
(7 COMPONENTS)
1
3
8
C3
2
7
12
ED MODEL
ANGULAR POSITIONED
DETECTOR
SM-C-649081
(32 COMPONENTS)
TP2420

Figure 2-3

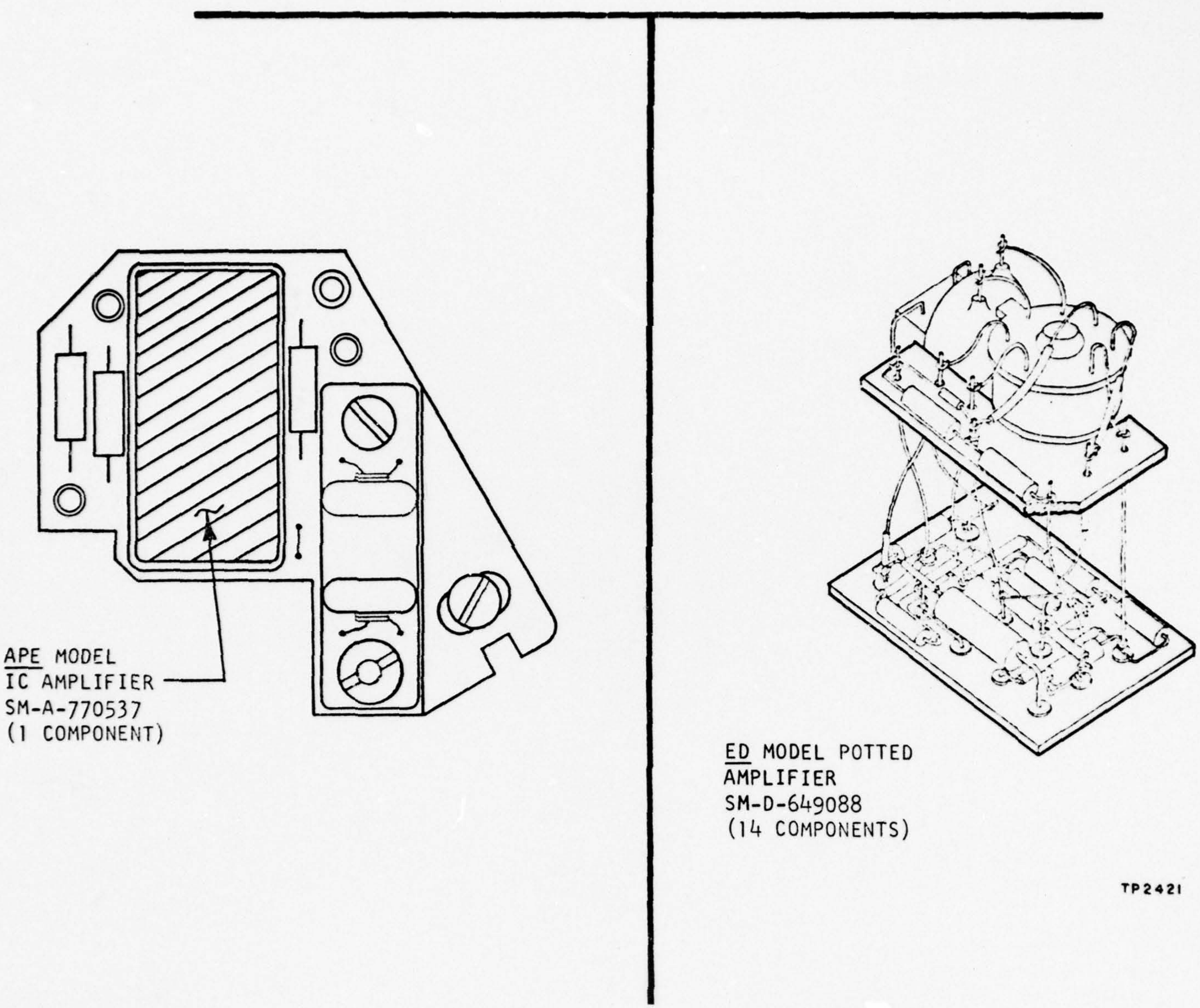

APE MODEL
IC AMPLIFIER
SM-A-770537
(1 COMPONENT)
ED MODEL POTTED
AMPLIFIER
SM-D-649088
(14 COMPONENTS)
TP2421

Figure 2-4.

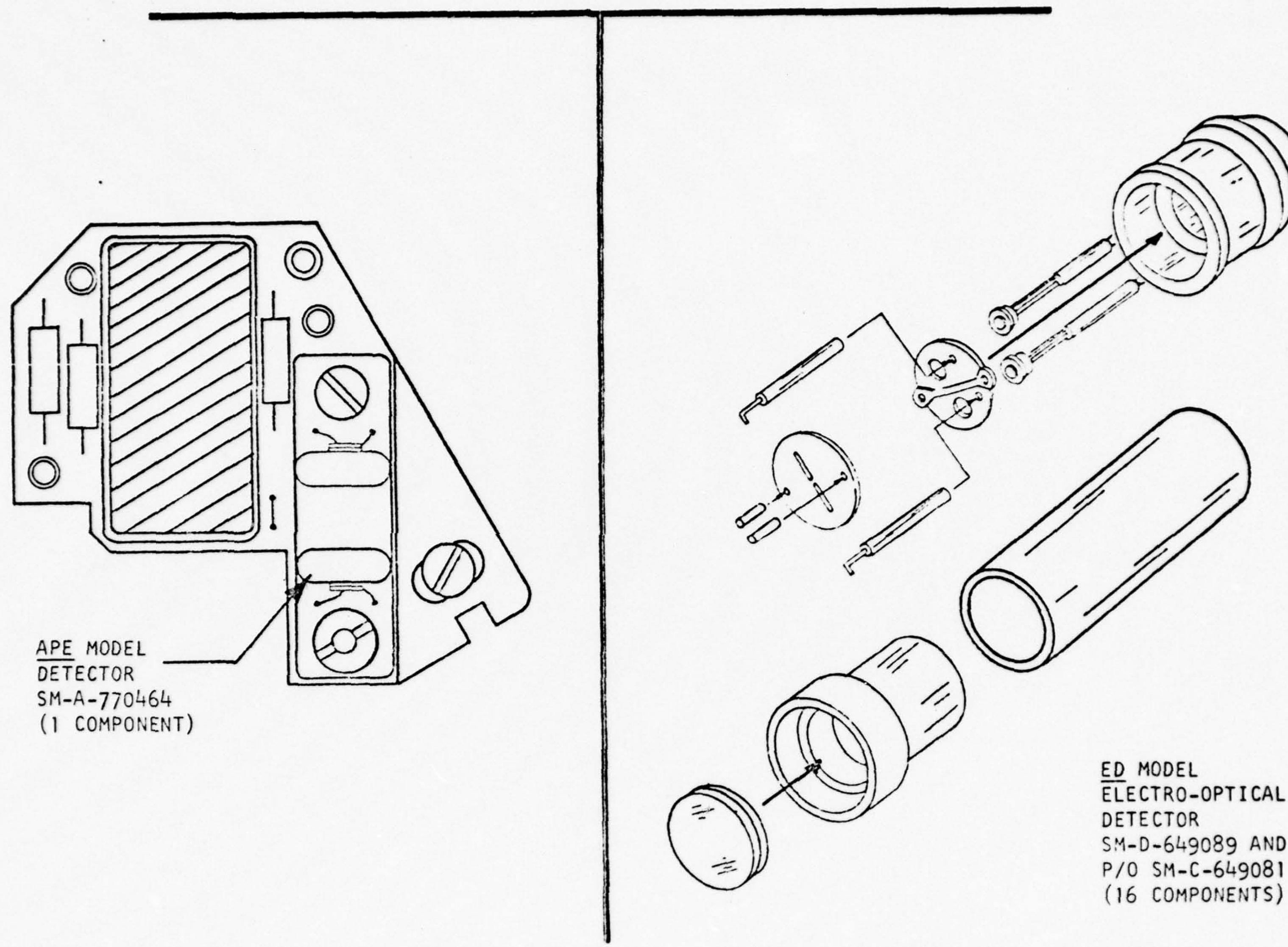

APE MODEL
DETECTOR
SM-A-770464
(1 COMPONENT)
ED MODEL
ELECTRO-OPTICAL
DETECTOR
SM-D-649089 AND
P/O SM-C-649081
(16 COMPONENTS)
TP2422

Figure 2-5

The hybrid resistor package was to contain 11 resistors which were to be laser trimmed to enable matching of detector responsivity. This approach would have enabled reducing the number of bias PC assemblies from 22 to 6. Additionally, a multilayered PC mother board and a printed flexible cable were to be incorporated to eliminate the extensive cabling required.

An order was placed with Sprague to fabricate the hybrid resistors. In parallel, designs of the new bias and mother PC boards as well as the printed cable were completed and prototype parts ordered. In July of 1973 it became apparent that Sprague was having difficulty in fabricating the resistor hybrid. Investigation revealed that the problem was centered on the use of nichrome for the resistance element which necessitated a 1/2 mil elemental line width. This elemental line width and the associated element spacing resulted in problems of bridging and voids that could not be overcome. An attempt was then made to use silicon/chrome, an experimental material at Sprague, as the resistive material which would have allowed a one mil line width thereby eliminating the bridging and void problems. The resulting silicon/chrome units produced were unstable and subject to drift.

At the time the nichrome problem was recognized it was decided to re-evaluate APE use of the ED design. It was found necessary to follow a parallel approach whereby either the hybrid design or the ED discrete design could be incorporated into the APE units.

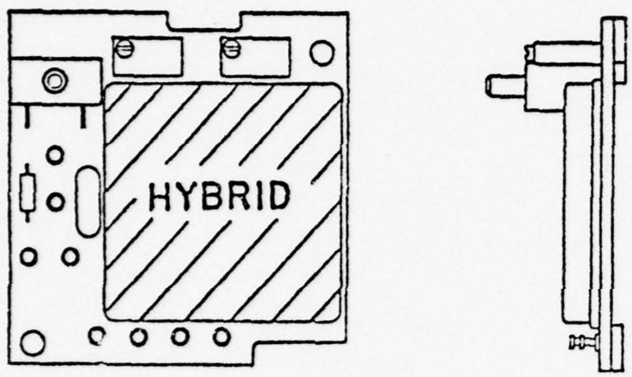
Late hybrid delivery slippage and the aforementioned silicon/chrome instability finally resulted in stoppage of all further resistor hybrid effort in January 1974. As a result the ED design was carried over into the APE models.

2.1.1.4 High Voltage Power Supply SM-D-770211

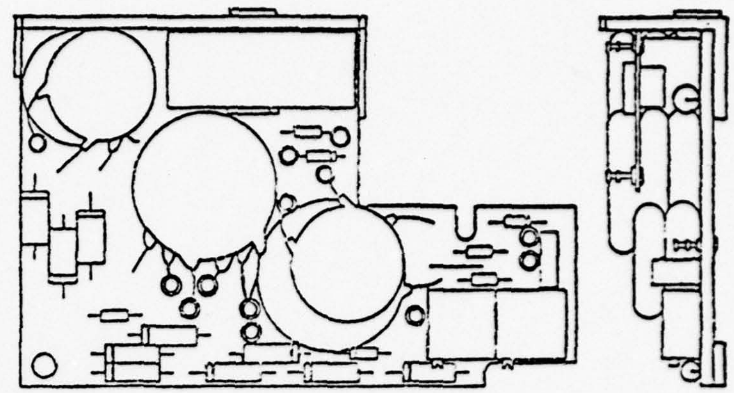
Figure 2-6 illustrates three versions of the high voltage power supply (HVPS). Shown are the ED model SM-D-649110, APE model SM-D-770211 and a hybrid model. Design of the hybrid microcircuit was initiated early in the APE program and it was intended that this would be incorporated in the final APE design. As can be seen in the illustration the hybrid model would have resulted in a significant size reduction as well as an approximate seven to one reduction in the number of discrete components.

Initially deliveries of the high voltage hybrid were scheduled for November 1973. However, during September 1973 it became apparent that initial deliveries would not be received until December. Schedules indicated that the December delivery might delay fabrication of the APE AN/TAS-3 units. It was therefore decided to perform a producibility review on the ED design of the HVPS. Further delivery and technical problems delayed receipt of the final hybrids until May 1974. Subsequent electrical testing of the hybrid indicated that electrical performance was acceptable, however, a failure during the screening acceleration test remained unresolved. As a result of the delay the hybrid was not used in the APE model.

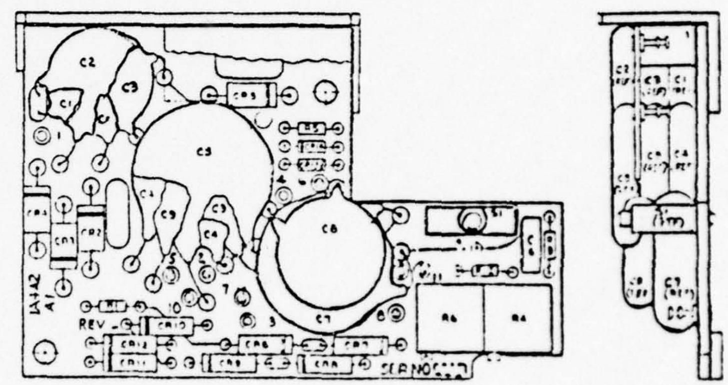
The major APE modification to the ED design was the substitution of a recently available, MIL standard interlock switch M8805/101-001 for the dedicated switch design which had been developed during the ED phase. This had a dual benefit in that assembly was simplified and that the ED switch design, which was suspect in several field failures, was eliminated.



APE HYBRID CONCEPT
HIGH VOLTAGE POWER
SUPPLY



ED MODEL
HIGH VOLTAGE POWER SUPPLY
SM-D-649110



APE MODEL
HIGH VOLTAGE POWER SUPPLY
SM-D-770211

TP2423

Figure 2-6

2.1.1.5 Scanner Electrical Assembly SM-D-649105

While performing laboratory tests of the APE Scanner Assembly, SM-D-770174, at low temperature -40°F (-40°C) it was noted that the ability of the motor to start at the low temperature was marginal. These results led to an investigation of motor drive circuitry on assembly SM-D-649105.

The original circuit used a flip-flop, 1A4A1U2 (TI, SNC54673T-06), which alternately switched providing a return for the motor current. Analysis of the circuit showed that at -40°F the flip-flop was current limiting and not able to adequately sink the motor current thereby reducing the efficiency of the motor. This reduction in efficiency, at low temperature, resulted in the marginal starting condition.

The circuit was then modified by using two pairs of NAND gate buffers configured as a flip-flop. This was accomplished by modifying the printed circuitry and substituting an M38510/00302BDB microcircuit for the TI device at 1A4A1U2. Each gate in the new device can provide three times the drive of the original TI unit. With the gates connected in parallel a further increase in drive is provided thereby assuring that sufficient motor current can be accommodated under all operating temperature conditions. This modification has another benefit, in that the available motor power has been increased thereby enabling a larger range of scan rate adjustment for the scanner mirror. The scan mirror scanning rate can now be adjusted to approximately 30 Hz/sec, without additional circuit changes. This additional adjustment range will be desirable for image improvement considerations, in future units.

Changes to the circuit were incorporated in the four APE units and tests performed. Results of the tests showed that the motor will start, in any position, at temperatures as low as -60°F (-51°C).

2.1.1.6 Logic Assembly SM-D-649102

During fabrication of the ED units a relatively high incidence of broken capacitors, C9 and C10, on the SM-D-649102 Logic Assembly was noted. This was investigated and it was determined that the capacitors are being damaged during handling of the completed assemblies and that their size and location on the assembly made them subject to damage. A review indicated that the capacitors could be reduced in physical size without requiring any other changes to the assembly, thereby significantly reducing the risk of damage. The resulting change substituted M39014/01-1455 for the M39014/02-0218 on the APE units.

2.1.1.7 EMI Modifications

During the latter part of 1972 the ED model of the AN/TAS-3 successfully passed EMI test in accordance with MIL-STD-461 and 462. Subsequently, in 1973, High Level Radiation Effects and Hazard tests were performed at Picatinny Arsenal. Results of the Picatinny tests indicated that some corrective action was required. It was determined, however, that because of the type of changes required it would not be possible to modify the existing ED units. Therefore, it was decided to incorporate the Picatinny recommendation in a modification of the APE design.

Areas affected were the following:

- Tracker Cable
- Battery Power Leads
- Scanner Housing and Main Frame Front Support.

Tracker Cable - The tracker cable used on the ED units was a modification of parts used on the DRAGON Tracker and Launch Tube. Picatinny's recommendation was that the cable be completely shielded. Design of the shielding was discussed with both MDAC/TICO and Sanders. As a result of these discussions and to comply with the APE fabrication schedule it was decided that PAVSC/GSD would develop the basic design of the shielding and Sanders would fabricate the cable. Requirements of the shielding enclosure necessitated removing the internal floating capability of the tracker connector and redesigning the connector mount to provide the float at the mounting to the AN/TAS-3 main frame. This was accomplished and Figure 2-7 illustrates the final cable design, SM-D-770439. Figure 2-8 shows the cable installed on the AN/TAS-3.

Battery Power Leads - Picatinny's recommendation to filter the battery leads necessitated inserting an immersion and EMI sealed filter module in the battery lead conduit between the battery connector and main frame. The design of the filter module is shown in Figure 2-9 and a photograph of the installation in the APE model of the AN/TAS-3 is shown in Figure 2-10.

Scanner Housing and Main Frame Front Support - The final recommendation necessitated a design change in the scanner housing SM-E-770728 and the front support SM-E-770837 to provide an added groove in these parts to enable an EMI gasket to be installed in addition to an existing "O" ring. Partial views of the housing and front support illustrating the added grooves are shown in Figures 2-11 and 2-12.

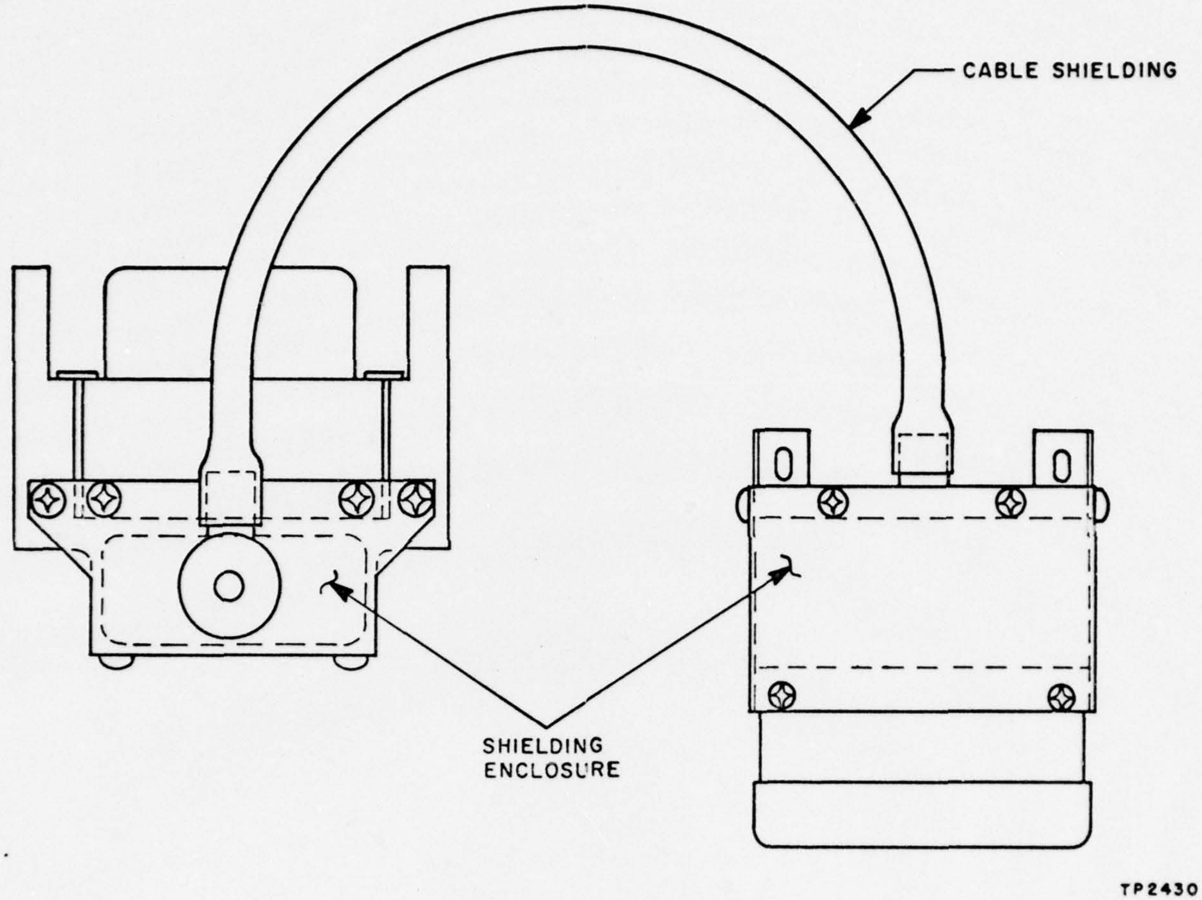


Figure 2-7. Shielded Tracker Cable, SM-D-770439

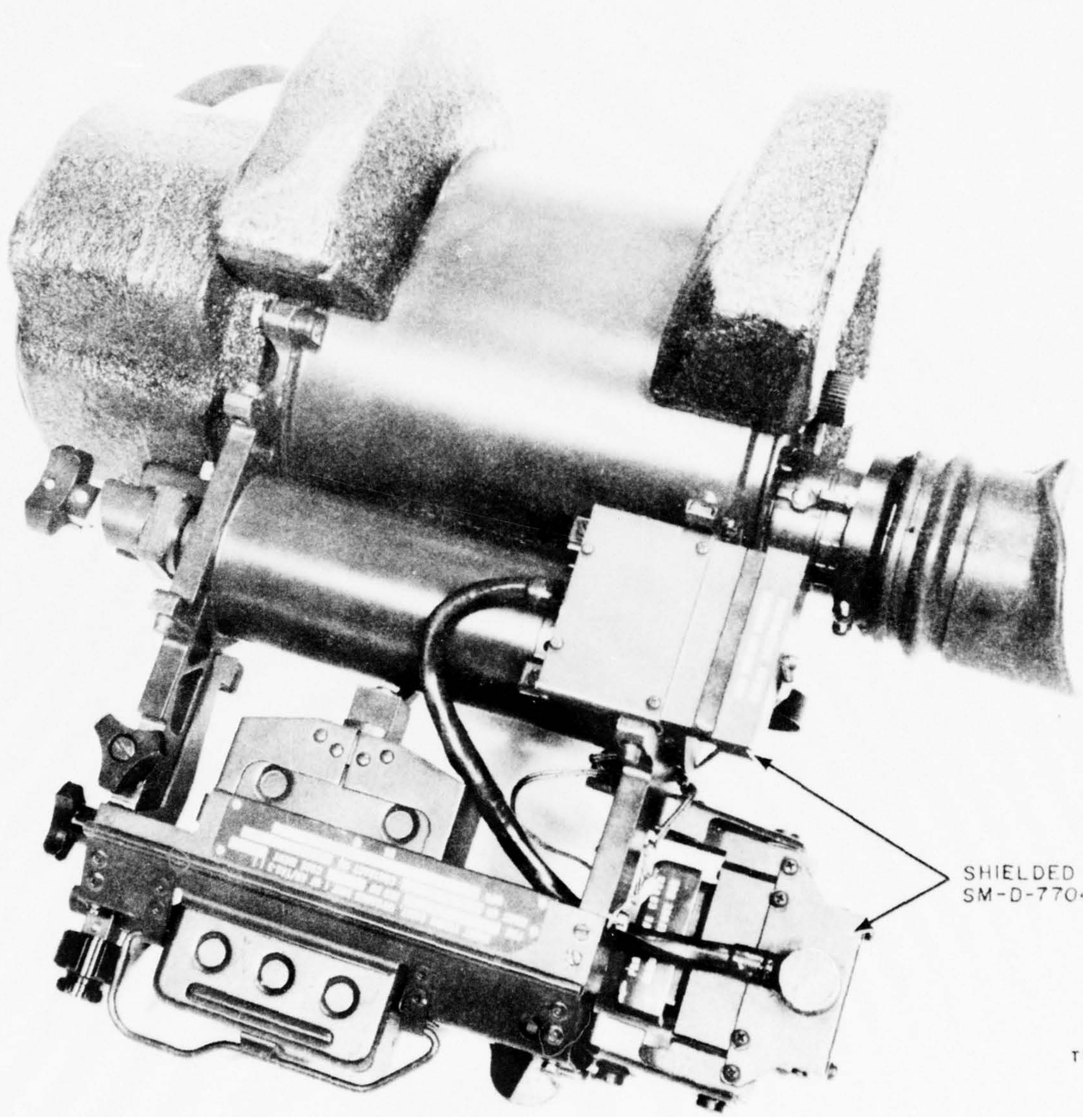


Figure 2-8. Shielded Cable Installation, AN/TAS-3 (APE Model)

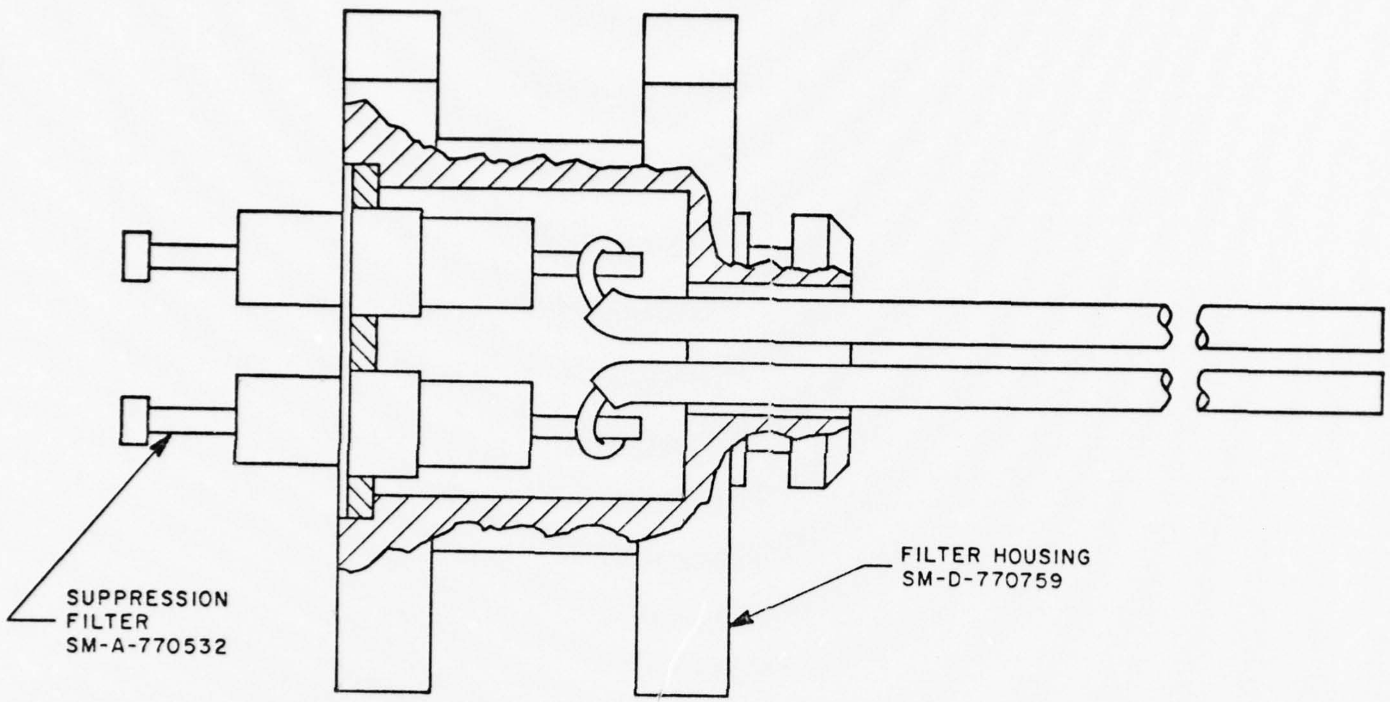


Figure 2-9. EMI Filter Assembly SM-D-770198

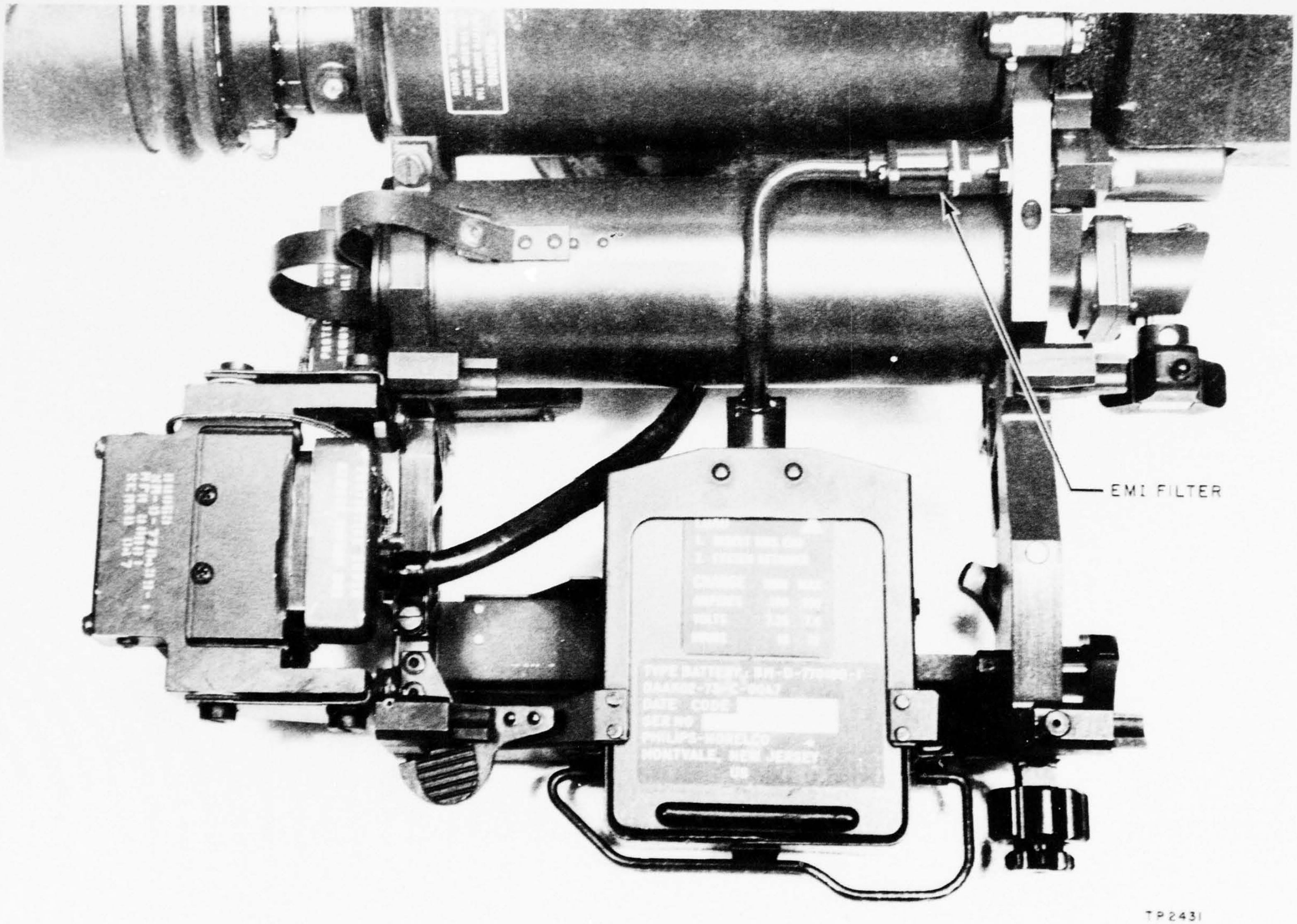


Figure 2-10. EMI Filter Installation, AN/TAS-3 (XP1 Model)

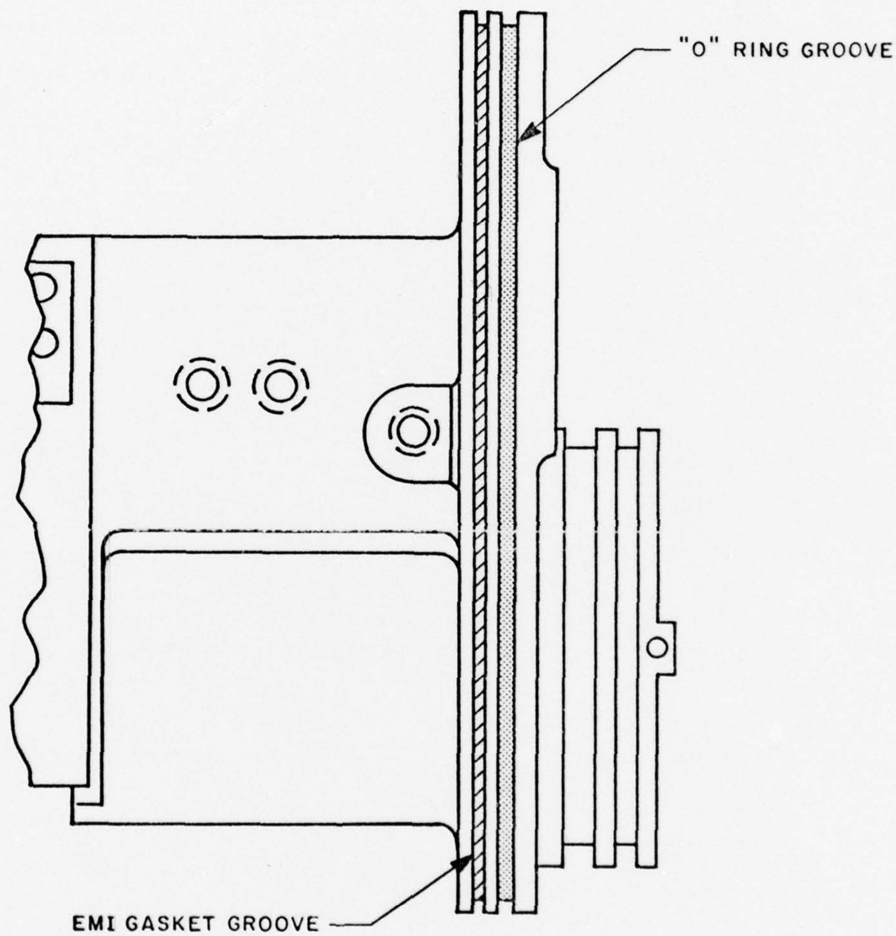


Figure 2-11. Partial View - Scanner Housing SM-E-770728

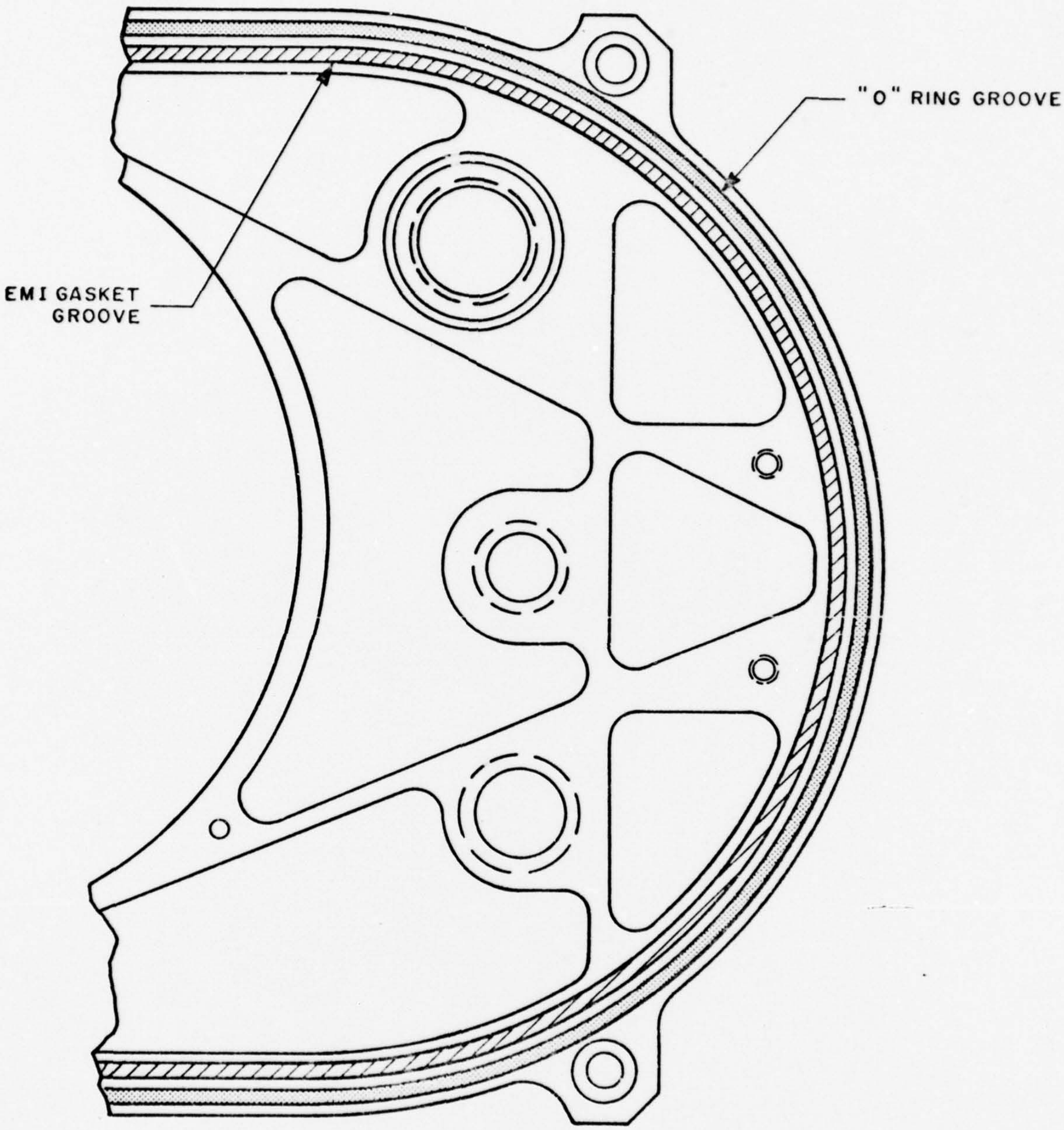


Figure 2-12. Partial View - Front Support SM-E-770837

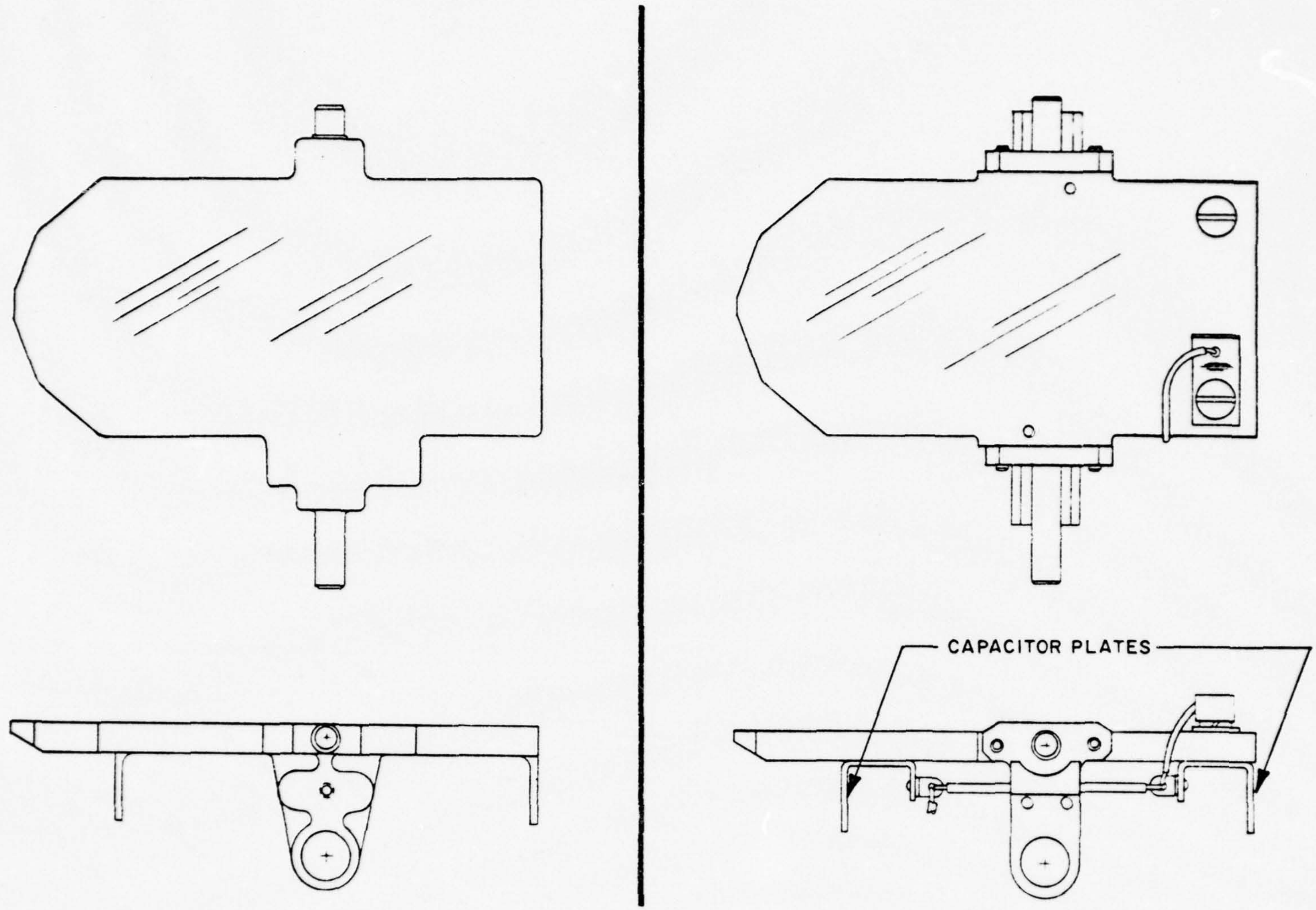
2.1.2 PRODUCIBILITY, MECHANICAL DESIGN

Mechanical review of the ED drawing package was directed at simplifying fabrication, assembly and test of the AN/TAS-3 to the greatest extent possible without sacrificing performance or field handling capabilities. All drawings were reviewed and as a result a significant number of dimensional changes were made. Changes included relaxed as well as tightened tolerances and in some cases completely redimensioning parts to eliminate tolerance buildup or to clarify the part. Parts were also monitored during the fabrication of the APE units and drawings modified as required, consistent with all requirements so as to reflect the parts as delivered and to minimize MRB action during any future production. Operations that required drilling and pining at assembly were eliminated to the greatest extent possible by fabricating parts with pre-drilled holes and where necessary, designing assembly fixtures to maintain the required tolerances. Critical assemblies were also reviwed to assure that the tolerance accumulation of piece parts were within the ranges required for final assembly. When fabricating production quantities excessive tolerance accumulation can create problems that are not readily apparent during fabrication of small lots.

A significant portion of the mechanical effort was associated with the electronic design and was discussed in paragraph 2.1.1.1 through 2.1.1.7. Other accomplishments are discussed in the following paragraphs.

2.1.2.1 Scanning Mirror, SM-D-770726

Figure 2-13 illustrates the comparison between the APE and ED models of the scanning mirror. The ED model required a number of drilling and pining



APE Model - One Piece Scanning Mirror
SM-D-770726

ED Model - 22 Piece Assembly
SM-D-649085 & P/O SM-D-649174

TP2464

Figure 2-13

operations at assembly in addition to cementing the capacitor plates in place. The APE model is a once piece mirror which eliminated all secondary operations.

2.1.2.2 <u>Objective Lens Assembly SM-D-770172</u>

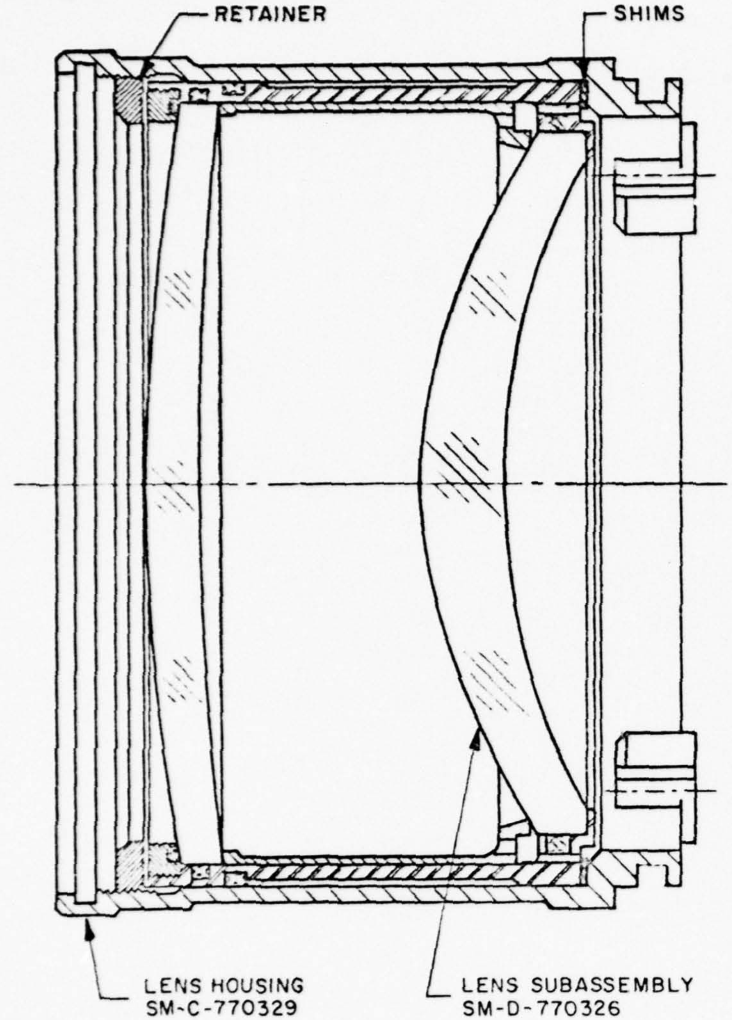
Specifications required that the AN/TAS-3 be fixed focus. This necessitated that a shimming operation be performed to compensate for variations in the optical path length to obtain final focus. In the ED model shims were placed between the detector and the scanner casting as shown in Figure 2-14. To perform this operation required removal of the scanner cover, disassembly of the scanner casting from the main frame and removal of the detector.

Initial efforts to simplify the procedure, were directed at providing a threaded focusing mount for the detector. Engineering models were fabricated and proved feasible for focusing, however, it was believed that this approcah might permit relative motion at the detector/scanner casting interface with a resultant degradation of performance.

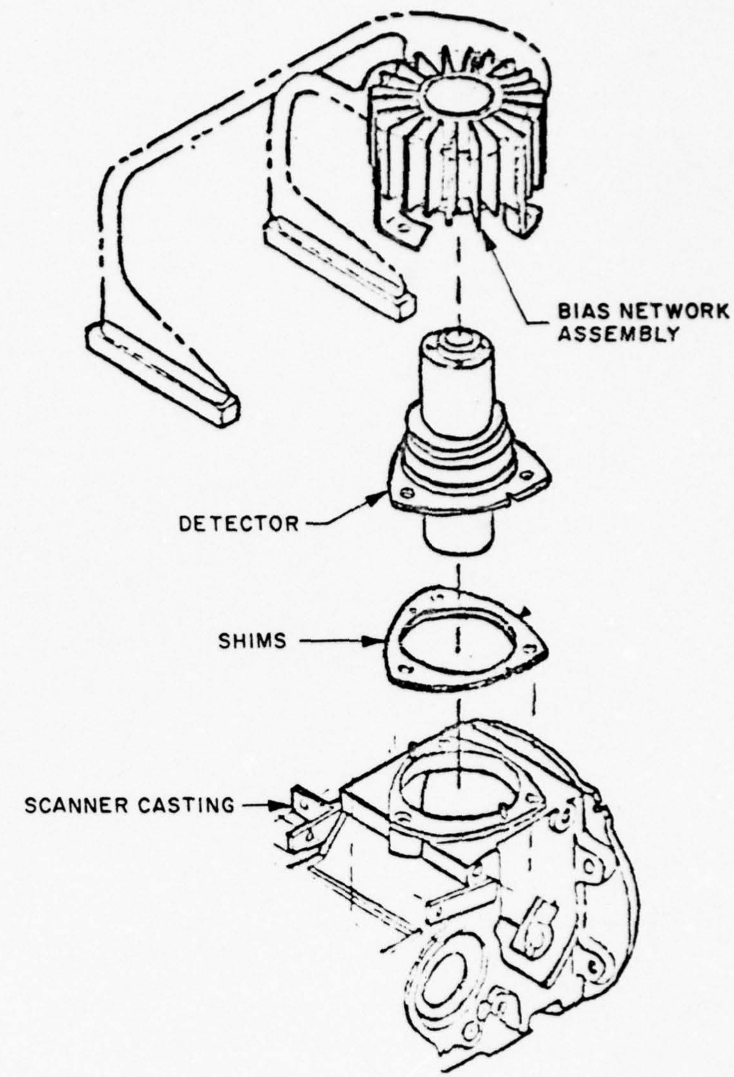
The resulting solution is shown in Figure 2-14. An objective lens subassembly, Figure 2-15 was designed to fit within the lens housing thereby enabling shimming between the subassembly and the housing. This design retained the rigidity of the ED model while simplifying the procedure and providing a greater range of adjustment.

2.1.2.3 <u>Battery Frame Subassembly SM-D-770254</u>

The ED model parts, equivalent to SM-D-770254, consisted of four separate pieces which required approximately 26 transfer drilling operations. In addition, maintaining the necessary tolerances while fabricating the ED unit, proved to be difficult. This design was modified in the APE program by reducing the number of parts to three and modifying the concept to allow the



APE Model - Method of Focus
Objective Lens Assembly
SM-D-770172



ED Model - Method of Focus

TP2460

Figure 2-14

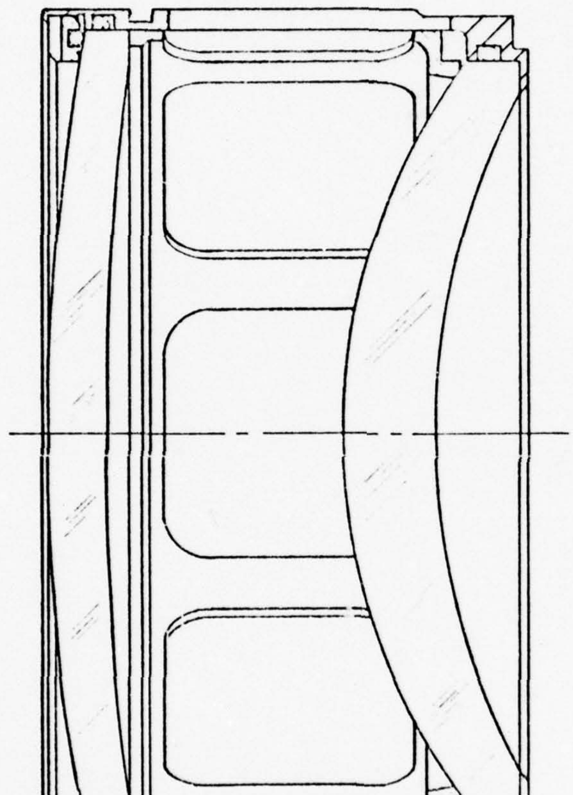


Figure 2-15. Objective Lens Subassembly SM-D-770326

TP2461

part to be fixtured so as to eliminate all but four transfer drilling operation. The APE configuration is illustrated in Figure 2-16.

2.1.2.4 Freon Filter/Dryer

During field testing of ED units EPR's were received indicating that freeze ups were occurring in the detector cooling system during operation. This problem was subsequently eliminated by installing a filter/dryer in the gas line between the valve and the cryostat. The filter/dryer in the ED models, was located within the cover of the AN/TAS-3 and required removal of the cover and loss of the system nitrogen purge for replacement. While the ED units were being modified the concept was being reviewed for the APE model. Results of the review showed that an external location for the filter/dryer would be a significant improvement, in that dryer capacity could increase, installation and replacement simplified and a cartridge concept used for the dryer element. A cross section of the resulting APE filter/dryer is shown in Figure 2-17. Figure 2-18 is a photograph of an installed unit.

2.1.2.5 Coolant Gas Noise Suppressor

At initial turn-on of an AN/TAS-3 the flow of coolant gas is at a relatively high rate because of the detector demand for rapid cool-down. This initial transient condition caused the external coolant gas pressure relief valve to emit a sputtering noise for about the first 10 seconds of operation. Several approaches to eliminating the sound were tested including different valves, varying spring rates in the valve and muffling the sound in the front lens cushion, however, none were successful. The final solution, as shown in Figure 2-19, was to apply a light off axis force to the poppet of the valve

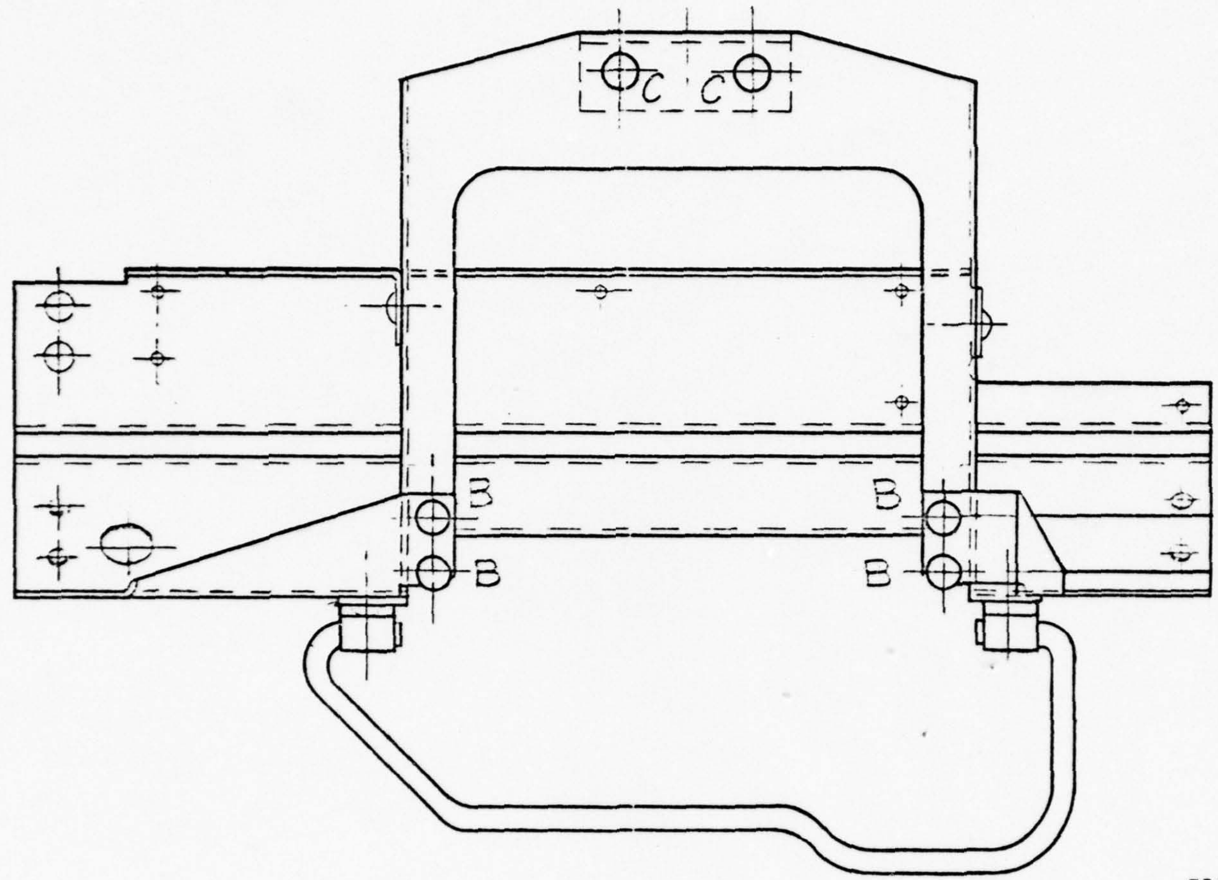


Figure 2-16. Battery Frame Subassembly SM-D-770254

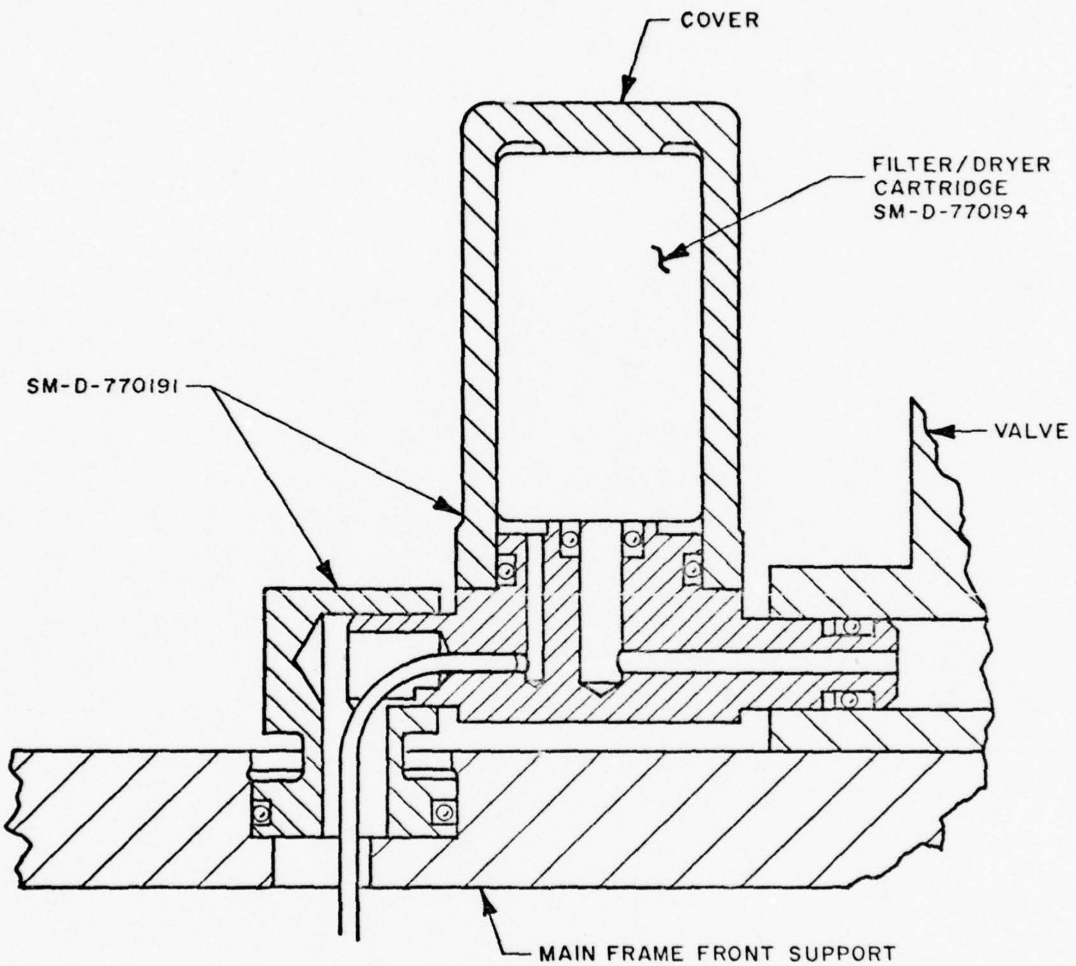


Figure 2-17. APE Model - Filter/Dryer
SM-D-770191 and SM-D-770194

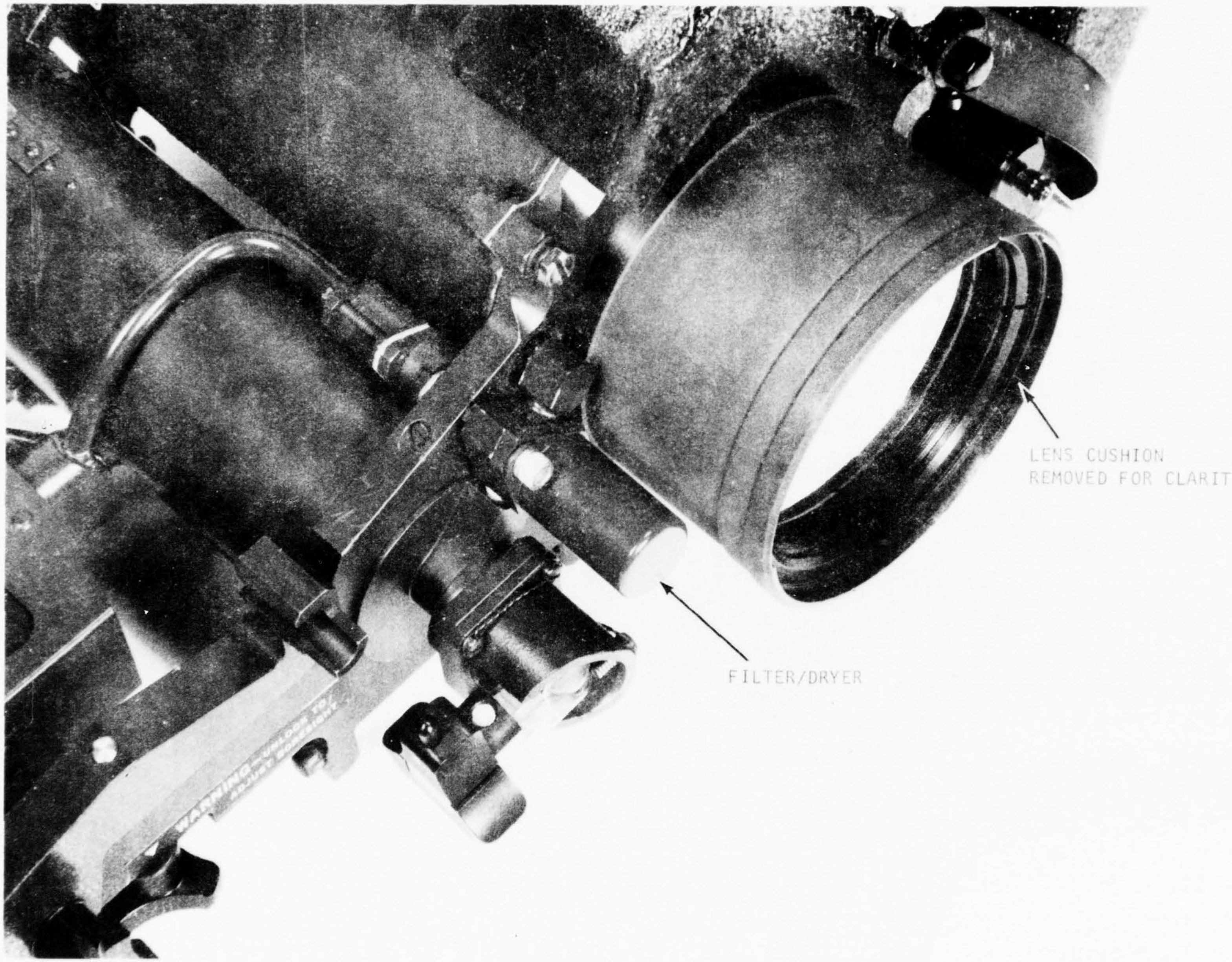


Figure 2-18. Installed Filter/Dryer

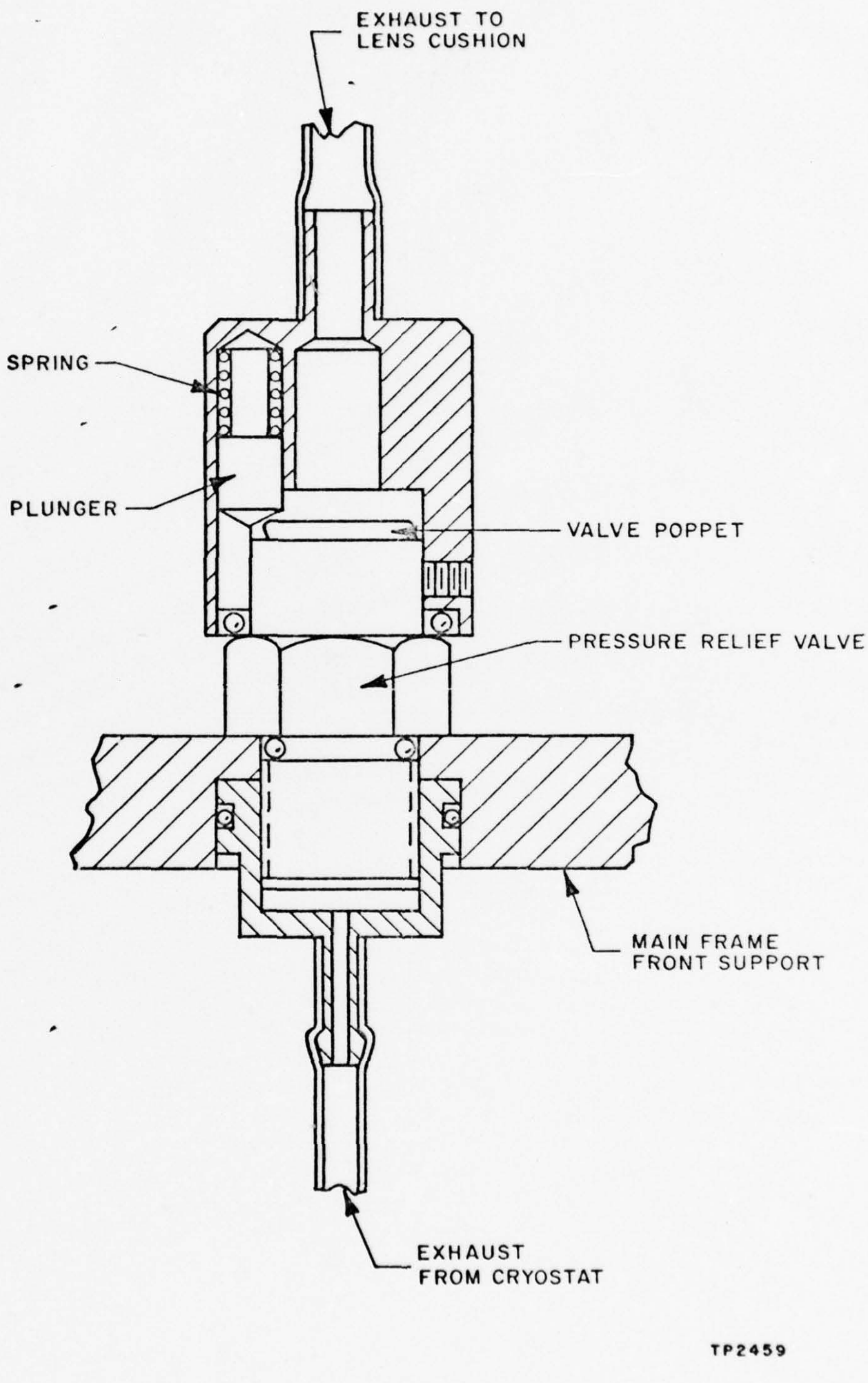


Figure 2-19. Coolant Gas Noise Suppressor

to dampen the oscillations, by means of a spring loaded plunger, and exhaust the gas into the lens cushion. This design proved acceptable and is installed on all APE units. Figure 2-20 is a photograph of a typical installation.

2.1.2.6 AN/TAS-3 Tracker Mount

Field testing of the AN/TAS-3 ED model demonstrated that boresight shifts between the Tracker and AN/TAS-3 were occurring at the night sight tracker mount. An immediate effort was started on the ED program to eliminate the boresight shift by modifying the tracker mount. During this period the APE program was in progress and it was recommended by APE personnel that while modifying the tracker mount consideration be given to eliminating the toggle linkage that actuated the engagement of the tracker connector. The reason was two fold in that elimination of the toggle linkage would significantly simplify fabrication and assembly of AN/TAS-3 main frame and eliminate a motion required by the DRAGON gunner to engage the connector.

The design modification was completed and ED units were subsequently successfully field tested. However, the ED design modifications were a retrofit of existing hardware and this necessitated some additional redesign to adapt the changes to the APE models. The evolution of the tracker mount can be seen in Figures 2-21 through 2-23 which are, respectively, Initial ED Tracker Mount, Modified ED Tracker Mount and the APE Tracker Mount.

2.1.2.7 Other Mechanical Producibility Modifications

Additional producibility modifications incorporated into the APE models are briefly described in this paragraph.

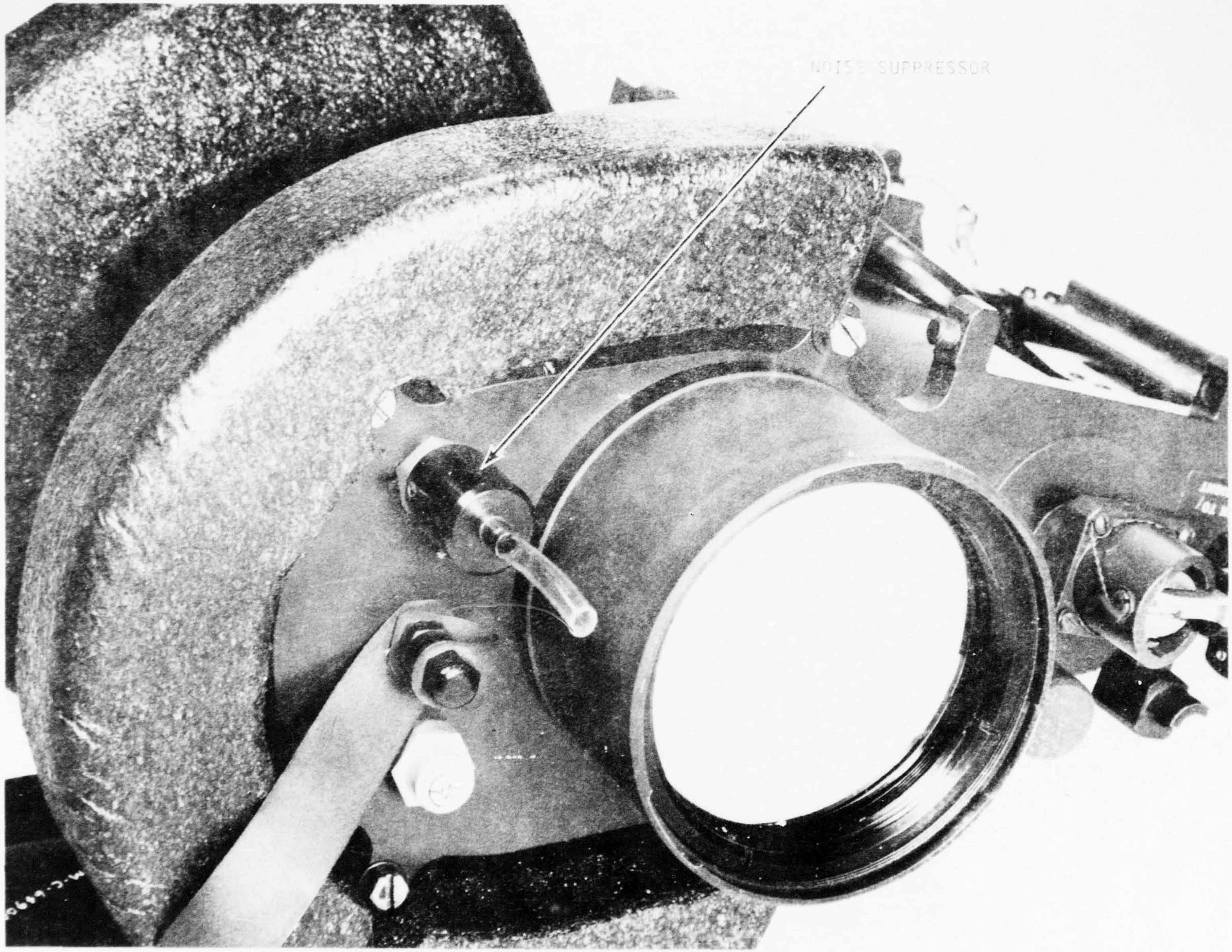


Figure 2-20. APE Model - Coolant Gas Noise Suppressor

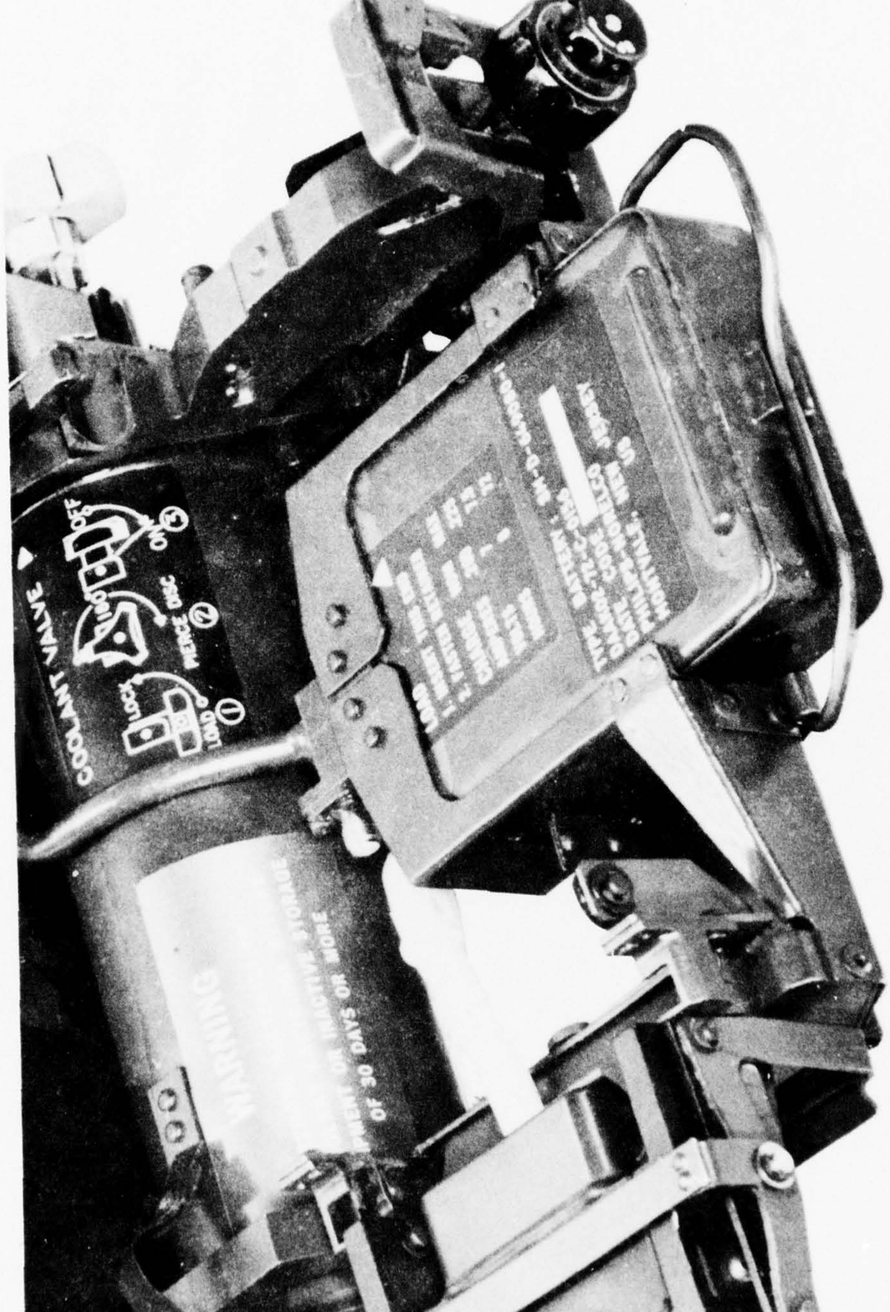


FIGURE 2-21 INITIAL ED TRACKER MOUNT

Figure 2-22 Modified ED Tracker Mount

Figure 2-23 APE Tracker Mount

Battery SM-D-770180 - Battery case tooling modified to incorporate integral thumb grip in drawn battery case to eliminate cementing on of separate piece. Battery retainer changed from machined part to casting to simplify fabrication. Battery retainer riveted to case in lieu of cementing, to eliminate field failures and simplify assembly. Connector redimensioned to eliminate tolerance build-up.

Terminal Board Subassembly SM-D-770236 - Terminal board changed to printed circuit to eliminate assembly of approximately 20 jumper wires and associated solder connections.

Tracker Mount and Boresight Adjustment - Operation and assembly of boresight adjustment simplified by eliminating unnecessary secondary elevation adjustment. Lead-in angle of tracker guides modified to provide improved engagement alignment with tracker connector. Boresight adjustment parts redimensioned to improve initial azimuth centering and eliminate tolerance build-up. Tracker release thumb-activator changed to casting to facilitate fabrication.

Scanner Housing SM-D-770328 - Transfer drilling operations eliminated to simplify assembly and provide improved alignment of attached parts.

Main Frame Front and Rear Supports - Consideration was given to changing the front and rear supports to casting, to eliminate extensive machining, however, an investigation determined that casting alloys would not provide adequate strength.

Eyeshield Assembly SM-D-649095 - The mold for the rubber eyeshield was modified to provide an internal shoulder. This shoulder plus a metal washer, which is cemented to the shoulder, provides additional support for the eyeshield eliminating the possibility of the eyeshield being disloged during field handling.

2.2 MAJOR SECOND SOURCE INVESTIGATIONS

In addition to the normal second and/or alternate source investigations performed by engineering and purchasing major investigations were conducted on a number of items that are discussed in the following paragraphs.

2.2.1 DETECTOR SM-D-770349

Initially detectors were procured from both SBRC and Optoelectronics for the AN/TAS-3 ED programs. The first detectors delivered by Optoelectronics developed soft vacuums and subsequently problems developed in their processing of arrays. PAVSC provided technical assistance to Optoelectronics in an effort to resolve the processing problems, however, this effort was not successful. Therefore in the early phases of the APE program, SBRC was the only qualified source for AN/TAS-3 detectors.

Further investigation of other potential sources by PAVSC, resulted in an order being placed with Infrared Industries Inc (IRI), in September 1973 for one AN/TAS-3 detector with options for up to nine additional detectors. IRI forecasted delivery of the first detector to PAVSC by March 1974 with qualified option quantity deliveries, if exercised, to start in August 1974.

Slippage in IRI's delivery was initially forecast in February 1974 with problems appearing to be centered in the dewar package and photomask. As it developed, however, IRI's inability to deliver was caused by unstable and noisy arrays. IRI continued to work on the problems but they were unsuccessful and the order was ultimately canceled.

SBRC remains the only qualified source for the AN/TAS-3 detector, at this time. It should be noted, however, that recent events at Optoelectronics have altered their position and they can again be considered as a potential source.

2.2.2 NICKEL-CADMIUM BATTERY CELL SM-A-770338

At the start of the APE program General Electric was the only source for the AN/TAS-3 Ni-Cad battery cells. In early 1973 GE indicated that, because of other production facility commitments, the lead time for the start of production deliveries would be up to twelve months. In addition, GE had been unwilling to accept all specification requirements because their product line was basically committed to commercial applications.

Because of the preceeding events PAVSC began a test program to compare the discharge characteristics of GE vs. Gulton battery cells. One set each of five cells in series, in accordance with the AN/TAS-3 configuration, were discharged into a 6 ohm static load to simulate AN/TAS-3 operating conditions.

Battery cells used were:

- GE GCR1.05ST
- Gulton 5R125
- Gulton SR100

Discharge tests were performed at -4°F, 28°F, 40°F, Room Temperature and 113°F. In all cases the discharge time, from full charge to 5.8 volts was greater for the Gulton battery cells with the 5R125 providing the longest discharge time. The increase in discharge time ranged from approximately 6% at -4°F to 24% at 113°F. A test under dynamic condition at room temperature, with the cell providing power to operate an AN/TAS-3 yielded similar results. Gulton cells, however, are approximately twice the cost of GE cells.

To establish Gulton as an alternate source all APE battery cells were procured from Gulton. The cells were assembled into batteries and subjected to

environmental tests with the AN/TAS-3 APE models. All tests were successfully passed. The Gulton 5R125 was thereby established as an alternate battery for the AN/TAS-3.

2.2.3 CARTRIDGE ASSEMBLY 7 CUBIC INCH, SM-D-770178

Kidde and TAVCO were the sources for cartridges in the ED phase of the program. It was intended to continue with these vendors throughout the APE phase and into production with Kidde being the prime source. PAVSC, however, continued to investigate other potential sources with the intent of developing a lower cost supplier. Results of this investigation were presented to the Government in the June 1973 DRAGON Quarterly Review held at PAVSC. Figure 2-24 is a copy of the cost analysis prepared for the Quarterly Review. At about the same time it was determined that the quantity of AN/TAS-3 units the Government was intending to procure was going to be substantially reduced (reduced from approximately 5000 to 300). It was also indicated to PAVSC that about 10 cartridges were to be required for each AN/TAS-3 or a total quantity of approximately 3000 cartridges. Based on the quantity forecast and quotations received it was decided that Kidde and TAVCO would be sufficient sources.

In November 1973 Kidde had a prolonged strike and this delayed finalization of the cartridge configuration for AN/TAS-3 APE units. At the termination of the Kidde strike, negotiations were resumed with the aim of finalizing the cartridge configuration (to assure that replaceable parts from all sources are interchangeable). A meeting was held with Kidde in early February 1974 at which time PAVSC's RFQ was discussed. Shortly after this there was a major reorganization at Kidde which involved management people directly associated with the AN/TAS-3 program. In March 1974 PAVSC had a meeting with Kidde management at which time Kidde reaffirmed their intention to continue in the AN/TAS-3 program and respond to PAVSC's RFQ.

1973 PRELIMINARY QUOTES 7 IN^3 CARTRIDGE AT COST TO PAVSC

QUANTITY	KIDDE			TA[illegible]		BRUNSWICK			CHANDLER EVANS		
	ENGRG CHG $3583 / UNIT COST	TOOLING	AMORT. TOOL UNIT COST	ENGRG CHG 0 / UNIT COST	TOOLING	UNIT COST	ENGRG CHG & TOOLING	AMORT. TOOL UNIT COST	UNIT COST	ENGRG CHG & TOOLING	AMORT. TOOL UNIT COST
25	$50.25		$200.00	$108.70		$128.40	16,665 E 58,316 T $74,981	$2999.24	$66.68	$34,287EBT	$1371.48
150	50.25	$5,000T	33.33	83.00		59.26	23,974 T	159.83	36.76		246.66
875	40.66		5.71	63.30		33.12	15,561 E 52,978 T 68,539	78.33	34.20	37,000 T	42.29
2,500	38.00		2.00	55.83	0	27.68	31,122 E 5,153 T 36,275	14.51	32.80		14.80
4,150	32.07	34,850T	8.40	51.50		21.55	525 T	0.13	31.50		8.92
15,000	24.86	56,610T	3.77	42.44		18.11	15,561 E 4,844 T 20,405	1.36	29.50	14,000 T	0.94
30,000	21.36		1.89	38.22		16.62	525 T	0.02	28.40		0.47
TOTAL ENGRG & TOOLING FOR 30,000 LOT BUY		$60,193 (2)			0 (3)		$225,224 (4)			$85,287 (5)	
UNIT COST FOR 30,000 LOT BUY WITH TOOLING & ENGR AMORTIZED (1)	$23.37			$38.22		$24.13			$31.24		

(1) ASSUMES INITIAL BUY OF 30,000 PIECES.
(2) KIDDE TOOLING CHARGES ARE NOT ADDITIVE.
(3) NO SEPARATE TOOL OR ENGINEERING CHARGES.
(4) ALL BRUNSWICK TOOL & ENGINEERING CHARGES ARE ADDITIVE FOR 30,000 LOT.
(5) ALL CHANDLER EVANS TOOL & ENGINEERING CHARGES ARE ADDITIVE FOR 30,000 LOT.

NOTES:

— COSTS DO NOT INCLUDE ENVIRONMENTAL OR QUALIFICATION TESTS.

Figure 2-24

During April, Kidde suddenly reversed its position and stated that they would not bid on the AN/TAS-3 APE requirements (Cartridges & Valves) nor would they bid on any future production orders.

A second meeting was held with Kidde management to reivew their new position. Kidde indicated that their No-Bid decision was based on limited future quantities forecast (3000 to 10,000 cartridges) and the inordinate amount of handling required to produce the part at their existing Belleville facility. In addition, the type of program required for the cartridge was no longer consistent with Kidde's future product line.

While the preceding developments were occurring at Kidde, PAVSC was in contact with TAVCO. In October 1973 a preliminary set of APE cartridge drawings was forwarded to TAVCO for review and comment. These drawings differed from the ED cartridge in that all parts normally removed from the cartridge for recharging purposes were completely detailed to assure interchangeability of these parts from all sources. After TAVCO's receipt of the drawings, delays developed at TAVCO over a proprietary rights issue which was not resolved until March 1974.

A formal RFQ, for APE cartridges, was sent to TAVCO on March 1, 1974. TAVCO did not respond to the RFQ until May 24, 1974 at which time the projected delivery of for six APE cartridges was 7 to 11 months.

When delays were encountered in obtaining replies from Kidde and TAVCO, PAVSC again solicited other sources for a charged cartridge. Brunswick Corp., was the only respondent, however, the required non-recurring charges could not be funded at that time.

By this time PAVSC had gained significant experience in recharging of the cartridges for the ED field tests. Therefore it was decided to solicit quota-

tions for an uncharged cartridge with PAVSC supplying all cartridge neck hardware, i.e., restrictors, burst disc---, and charging the cartridges. Approximately ten potential suppliers were solicited of which Pressure Pak, East Hampton, Conn., was the only responsive bidder.

In September 1974 an order was placed with Pressure Pak for 16 cartridges to be fabricated from AISI 4130 steel. Tests to be performed were:

- Magnetic Particle
- Radiographic
- Total Expansion
- Permanent Expansion
- Helium Leak
- Cleanliness
- Hydrostatic Burst
- Hydrostatic Cycling
- Microstructure
- Charpy "V" Notch (65°F and +155°F)

By early December 1974 all tests except Cleanliness were successfully completed. Some initial problems were encountered in meeting the cleanliness requirements, however, this was resolved and the cartridges delivered to PAVSC in January 1975.

Restrictors were then installed in a sample quantity of the cartridges and the cartridges charged with Freon. The filled cartridges were then submitted for particulate contamination analysis. Results of the test showed that the particulate count was within specification requirements.

Further investigation was made, as to adding a corrosion resistant coating to the unprotected parts of the cartridge. Pressue Pak subsequently had two sample cartridges oxide coated internally and externally, by the Leeds and Northrup Steam Homo Process. After receipt the cartridges were sectioned and subjected to ten day humidity test in accordance with MIL-STD-810B, Method 507,

Procedure I. Some areas of corrosion were noted after the test, however, the coating did provide a high degree of corrosion protection. Any future procurement of 4130 cartridges will be oxide coated in addition to the normal paint finish.

2.2.4 VALVE ASSEMBLY SM-D-649251

The coolant valve assembly SM-D-649251 had been developed by W. Kidde Inc., Belleville, N.J. for the ED models of the AN/TAS-3. Bendix Instrument and Life Support Division, Davenport, Iowa had also been considered, however, since Kidde was also fabricating the coolant gas cartridge, which interfaced with the valve, Kidde was the logical choice for the ED phase.

Bendix was again considered as a second source for the APE program and any resulting production. Two problems remained, however, (1) actuation of the Bendix valve would require the DRAGON gunner to perform motions significantly different from those required for operation of the Kidde valve, and (2) approximately $90,000 in non-recurring costs were required by Bendix. It was decided that two different operating modes and the non-recurring costs were not acceptable. Further consideration of Bendix was stopped.

Negotiations continued with Kidde for procurement of the APE valves and although some problems remained to be resolved negotiations appeared to be nearing completion in mid-March 1974. Suddenly in early April 1974, Kidde reversed its position and decided to "No Bid" the Valve and Cartridge (Refer to Paragraph 2.2.3).

As a result of the Kidde decision Bendix and other potential sources were requested to submit bids. The position of Bendix remained unchanged and the

other vendors no-bid. Meanwhile PAVSC obtained drawings of the detail valve parts. After reviewing the drawings, it was decided that PAVSC would buy piece parts for the valve and perform the assembly in-house. A producibility review of the drawings resulted in some dimensional and tolerance changes to satisfy operating requirements and facilitate assembly. Valves for the APE units were subsequently fabricated, assembled and installed in the units. Performance of PAVSC valves has been acceptable.

2.2.5 CATHODE RAY TUBE (CRT) SM-A-649236

Throughout the ED and APE programs PAVSC had a continuing effort to obtain an alternate source for the CRT which was being procured from Thomas Electronics. Although the Thomas parts performed satisfactorily, an alternate source was sought to improve both the competitive and supply aspects of the program.

During the ED phase numerous sources were solicited with RCA being the only supplier to respond within both the technical and cost limitations.

In 1972 an order was placed with RCA for CRT's. RCA proceeded on the design of the tube until April of 1973 at which time, for technical reasons, they abandoned their original design and proceeded with redesigned electron optics. Three of the redesigned CRT's were received in October 1973. Subsequent tests revealed that the tubes required excessive anode current. The required anode current would have degraded DNS battery performance. The CRT's were rejected and further effort with RCA was terminated.

Subsequently an order was placed with Special Purpose Technology Corp., Van Nuys, California for CRT's to be evaluated for the APE program. After

receipt four CRT's were tested and it was determined that the line width exceeded specifications. These tubes were accepted for test purposes. At this time all further second source investigations were stopped.

2.3 MANUFACTURING METHODS

A major portion of the APE program was devoted to establishing all manufacturing methods and tooling required for production of the AN/TAS-3. The required effort included the following items:

- Composite Bill of Material
- Assembly Flow Chart
- Assembly Floor Plan
- Assembly Operation Procedures
- Inspection Procedures
- Test Procedures
- Tooling.

All items were completed and documented under a separate Contract Item. Refer to CDRL No. A014, Contract DAAK02-73-C-0047, Final Production Plan, GSDR No. 815, dated June 12, 1975.

2.4 COMPUTERIZED AUTOMATIC TEST SET (CATS)

At the onset of the APE program it had been anticipated that production requirements for the AN/TAS-3 might necessitate the use of computerized automatic testing. As part of the contractual requirements PAVSC performed a study to determine the feasibility of utilizing a CATS for production testing. The study report, CDRL #A023, PAVSC GSDR No. 569 was delivered on June 20, 1973 and is attached as Appendix A to this report.

2.5 DIFFERENCES DRAGON "APE" Vs. ED MODEL, AN/TAS-3

In the performance of the APE program a number of producibility changes were incorporated into the APE model AN/TAS-3. Additionally, changes were also made to correct difficiencies noted in field test of the ED model AN/TAS-3. The major differences are noted in Figure 2-25. Applicable part numbers and illustrations in this report are noted.

ITEM	APE MODEL AN/TAS-3	EQUIVALENT ED PART	FIGURE
Noise Suppressors	P/O SM-D-770171	___	2-19, 2-20
Objective Lens Assy	SM-D-770172	SM-D-649072	2-14
Main Frame Assy	SM-D-770173	SM-D-649073	2-21, 2-22, 2-23
Low Voltage Power Supply	SM-D-770179	SM-D-649079	2-1, 2-2
Battery Assembly	SM-D-770180	SM-D-649080	___
Filter-Dryer Assy	SM-D-770191	___	2-17, 2-18
Cartridge, Filter-Dryer	SM-D-770194	___	2-17
EMI Filter Assy	SM-D-770198	___	2-10
High Voltage Power Supply	SM-D-770211	SM-D-649110	2-6
Boresight Pulse Generator	SM-C-770221	SM-C-649081	2-3, 2-4, 2-5
Cover Assy, High Voltage	SM-D-770234	SM-D-649133	___
Terminal Board Subassy	SM-D-770236	SM-C-649136	
Battery Frame Subassy	SM-D-770254	___	2-16
Scanner Elec. Subassy	SM-D-770305	SM-D-649205	___
Cable Special Purpose	SM-D-770439	SM-D-649339	2-7, 2-8
Mirror, Scanner	SM-D-770726	___	2-13

Figure 2-25. Major Differences APE Vs. ED Model AN/TAS-3

SECTION III

SPECIAL ACCEPTANCE INSPECTION EQUIPMENT (SAIE)

3.1 GENERAL

Requirements for the APE program included the development and fabrication of SAIE Test Stations for production test of the AN/TAS-3. The stations were successfully completed and verified during the program.

Thirteen SAIE stations were required as follows:

SAIE NO.	UNIT TESTED
1	Detector/Bias Network Assy
2	Preamplifier/Multiplexer/Logic/Interconnect Assy
3A	Boresight Pulse Generator Assy
3B	Scanner Electrical Assy (Circuit Card0
3C	Scanner Assembly
4	Scanner Assembly (Display)
5A	Low Voltage Power Supply
5B	High Voltage Power Supply
6A	Eyepiece Assembly
6B	Objective Lens Assembly
7	Scanner Assembly (Mechanical)
8	Gas Leak Detection
9	Audible Noise
10	Main Frame Assembly
11	Eyepiece Assembly (Light Leakage)
12	Boresight
13	Minimum Resolvable Temperature (MRT)

A brief description of each SAIE station is given in the following paragraphs.

3.2 SAIE DESCRIPTION

SAIE No. 1 - Figure 3-1 - Performs an operational check of the SM-D-770196 Detector, Cryostat Circuit Card Assembly by checking the cool down time, signal uniformity and noise on each detector element.

SAIE No. 2 - Figure 3-2 - Simulates all input signals and voltages to test the timing waveforms, multiplexing, and bias voltage resistors of the SM-D-649077 Preamplifier and Multiplexer Assembly.

SAIE No. 3A - Figure 3-3 - Tests operation of the SM-D-770221 Boresight Pulse Generator Assembly by testing the light emitting diode/photo transistor, amplifier gain, and waveforms.

SAIE No. 3B - Figure 3-3 - Tests the following parameters of the SM-D-649105 Scanner-Circuit Card Assembly. Motor drive circuitry and capability, horizontal signal and waveshape, cross hair enable signal, 300 kHz system oscillator, and cross hair circuitry associated with the scanner board.

SAIE No. 3C - Figure 3-3 - Electrically tests the SM-D-770174 Scanner Assembly for the following parameters. Motor drive capability, horizontal signal waveshape and amplitude, cross hair enable signal, 300 kHz system oscillator, and cross hair circuits associated with the scanner board.

SAIE No. 4 - Figure 3-4 - Simulates all signals and voltages necessary to display video raster and reticle on CRT of the SM-D-770174-1 Night Vision Sight, Infrared Display (Scanner) Assembly. Also tested are low and high voltage power supply voltage amplitudes, scanner speed, CRT deflection signals, and all CRT adjustment controls.

SAIE No. 5A - Figure 3-5 - Tests the SM-D-770179 Low Voltage Power Supply Assembly by measuring all output voltages and input currents at half and full load. Also tested is the noise generated by the switching regulator, all timing signals, and the 300 volt generated square wave to be used for the high voltage power supply.

SAIE No. 5B - Figure 3-5 - Tests the SM-D-770721 Circuit Card Assembly High Voltage. The following parameters are checked. Voltage doublers, voltage dividers, ripple and noise spikes, and voltages for focus and cutoff control.

SAIE 6A - Figure 3-6 - Checks the transmission, resolution, and focal characteristics of the SM-D-649076 Eyepiece Assembly.

SAIE 6B - Figure 3-7 - Tests the following parameters of the SM-D-770172 Objective Lens Cell Assembly. Focal length, resolution, and transmittance. This is done by plotting a line spread function and converting it to a modulation transfer function via a external digital computer.

SAIE No. 7 - Figure 3-8 - Sets up and tests the CRT aspect ratio, centering, and vertical reticle positioning of the SM-D-770171 Night Vision Sight, Scanner Assembly.

SAIE No.8 - Figure 3-9 - SAIE #8 performs all necessary tests to check for Freon 14 leaks around cryostat, gas valve, and tubing of the SM-E-770171 without access cover, and nitrogen leaks of complete system with cover installed.

SAIE No. 9 - Figure 3-10 - Tests the SM-E-770171 Night Vision Sight, Scanner Assembly for audible noise emitted during normal operation.

SAIE No. 10 - Figure 3-11 - Test the SM-D-770173 Main Frame Assembly, launch tube connector engagement, tracker connector engagement, and electrical continuity of launch tube-tracker cable.

SAIE No. 11 - Figure 3-12 - Tests the presence and level of any light being emitted from the SM-D-649076 Eyepiece Assembly when its security shutter is closed.

SAIE No. 12 - Figure 3-13 - Tests boresight cradle movement and repeatability by insertion of a tracker simulator into the SM-E-770173 Main Frame Assembly.

SAIE No. 13 - Figure 3-14 - Tests the SM-E-770171 Night Vision Sight, Scanner Assembly to determine the minimum resolvable temperature tolerance which a system will detect.

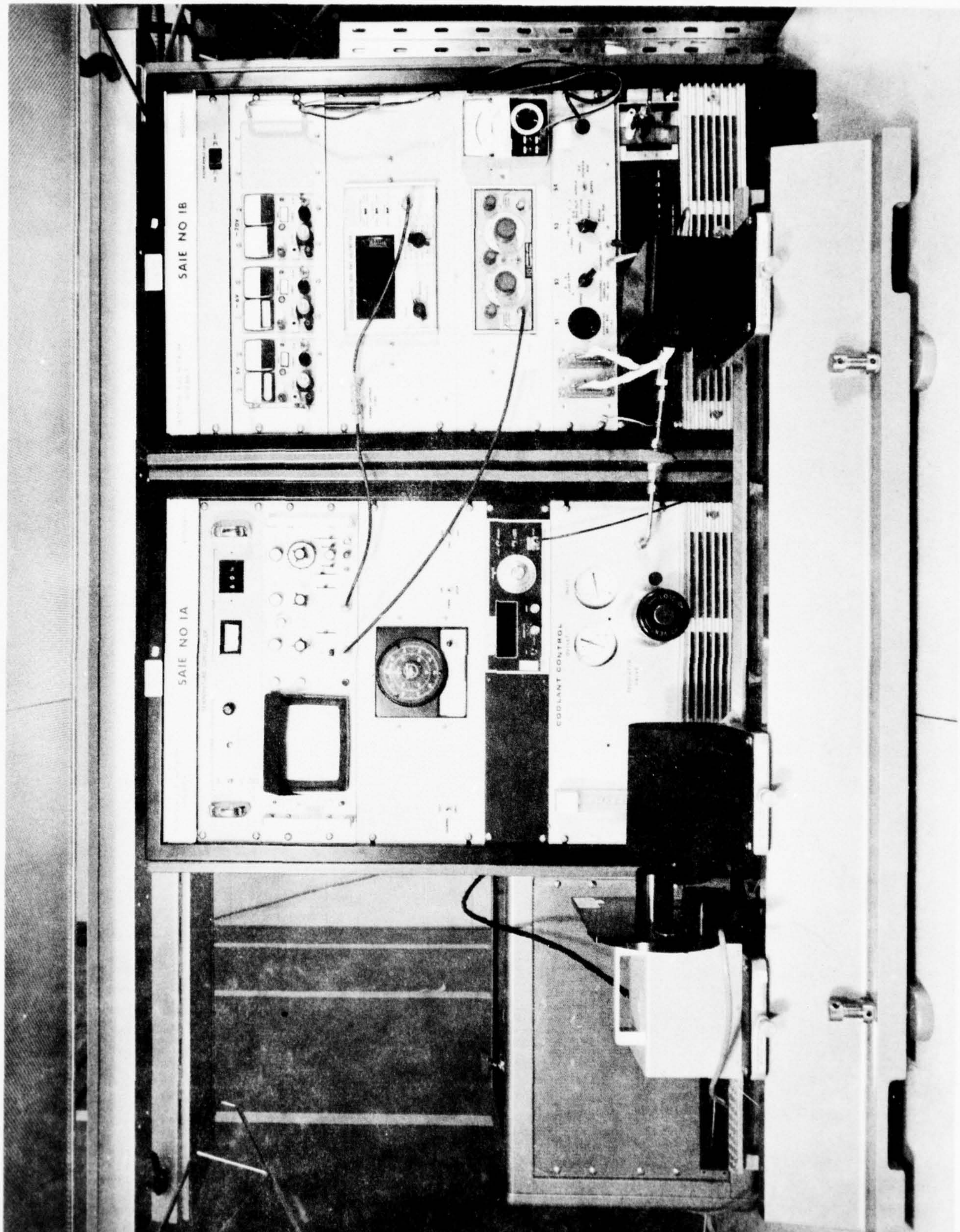


FIGURE 3-1

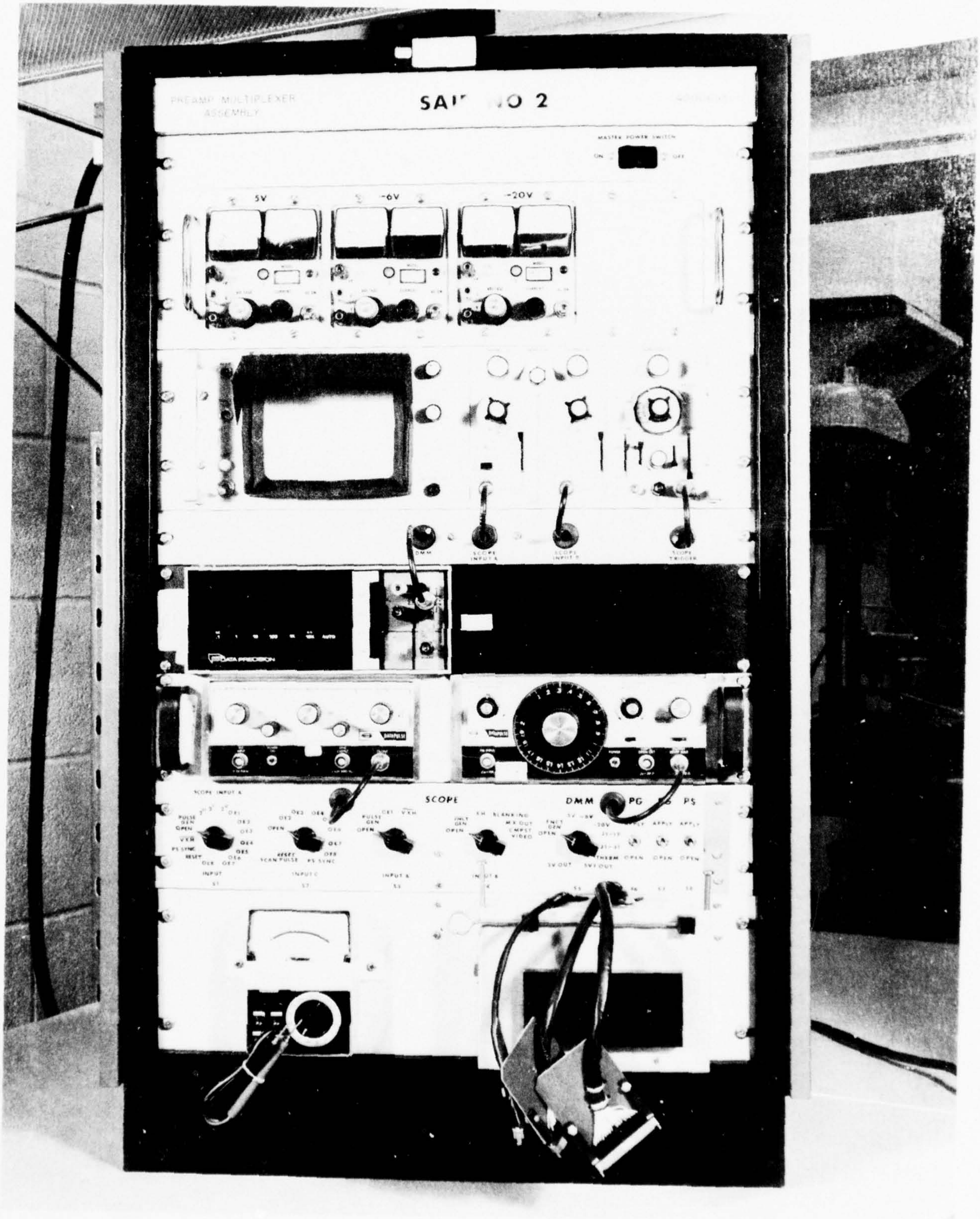

SAI NO 2
PREAMP MULTIPLEXER
ASSEMBLY
MASTER POWER SWITCH
5V
-6V
-20V
DMM
SCOPE
INPUT A
SCOPE
TRIGGER
DATA PRECISION
SCOPE
DMM
PG
PS

FIGURE 3-2

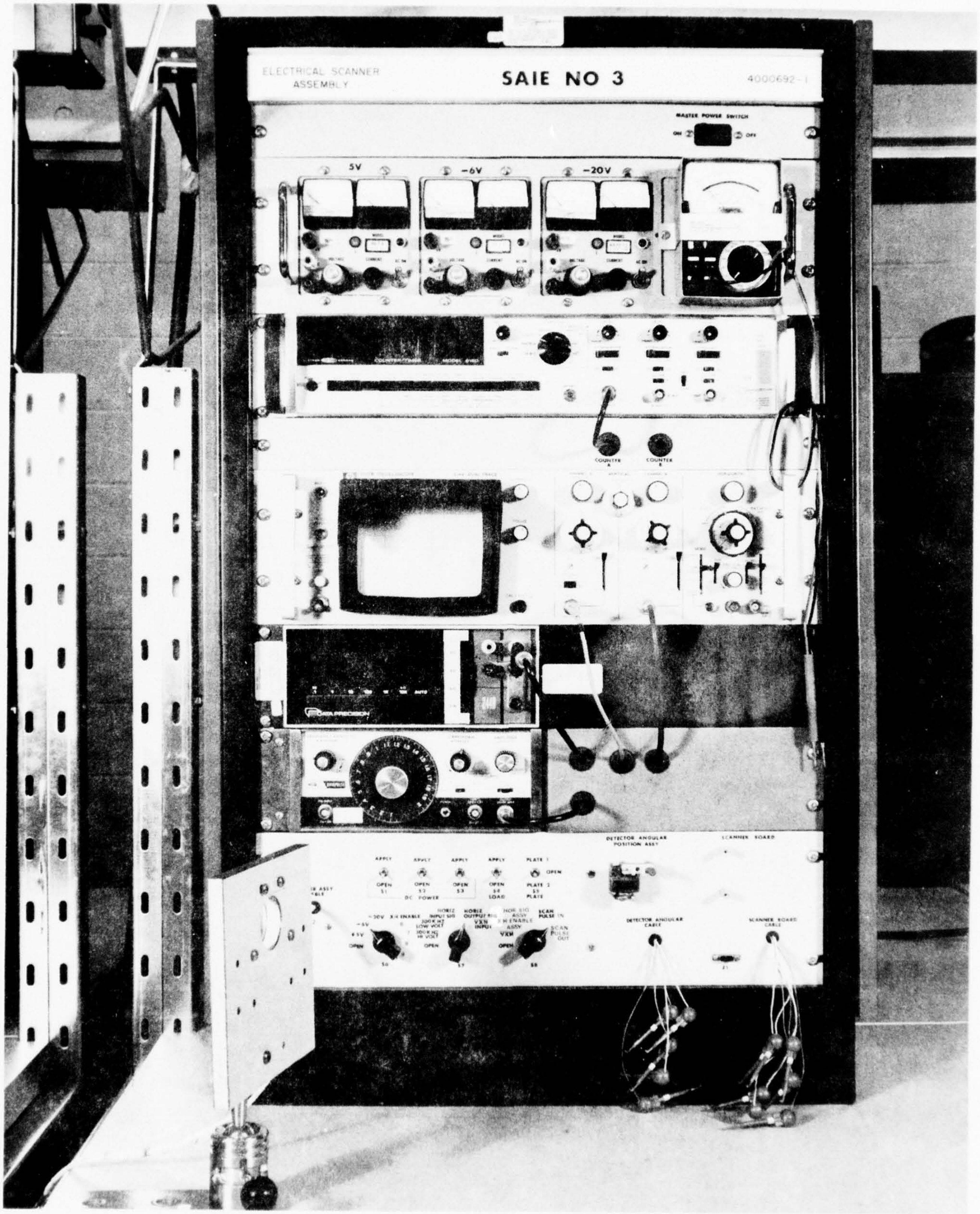

ELECTRICAL SCANNER ASSEMBLY
SAIE NO 3
4000692-1
MASTER POWER SWITCH
5V
-6V
-20V
COUNTER A
COUNTER B
DATA PRECISION
DETECTOR ANGULAR POSITION ASSY
SCANNER BOARD
DETECTOR ANGULAR CABLE
SCANNER BOARD CABLE

FIGURE 3-3

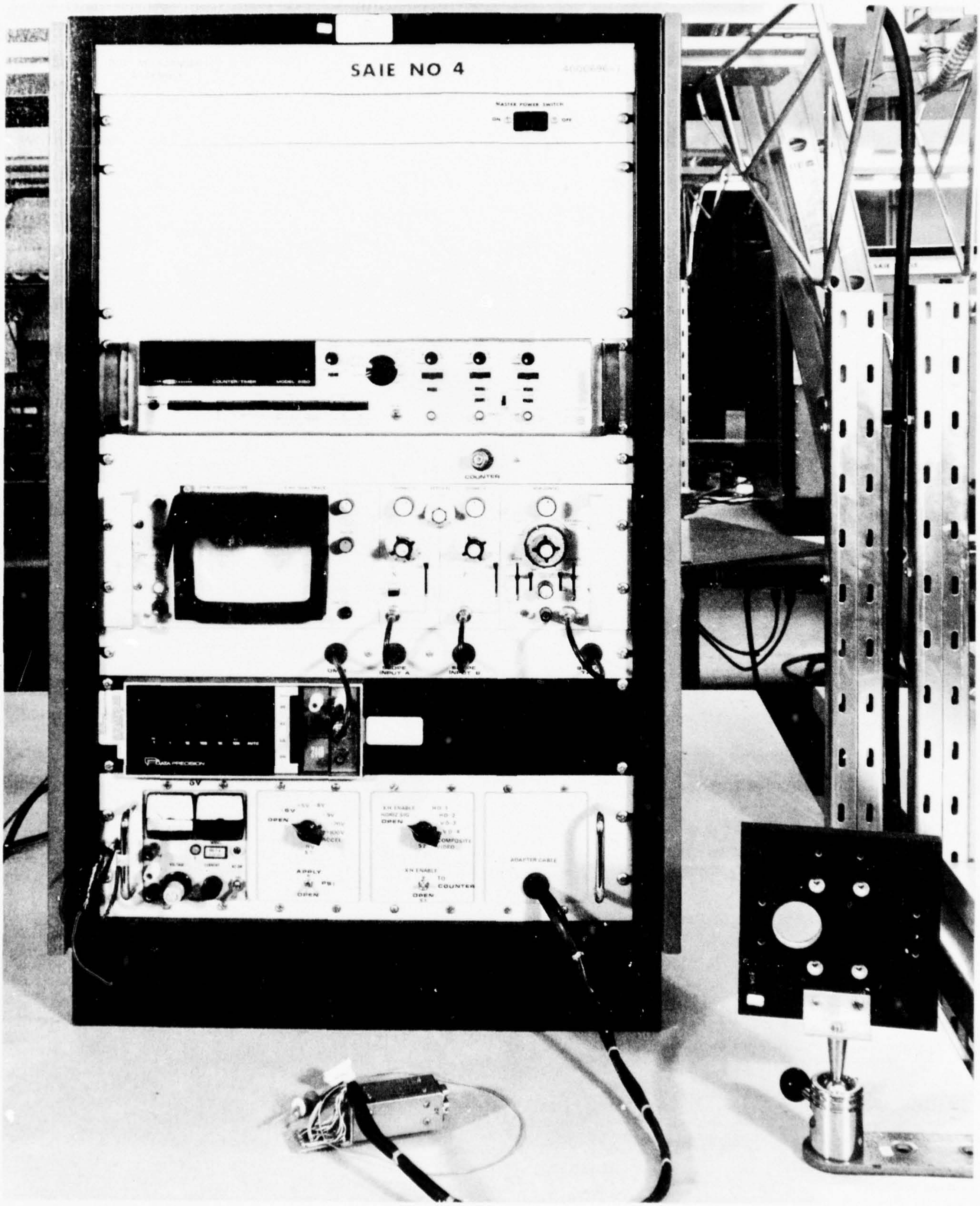

SAIE NO 4
COUNTER
DATA PRECISION
5V
OPEN
APPLY
OPEN
XN ENABLE
HORIZ SIG
OPEN
COMPOSITE
XN ENABLE
TO
COUNTER
OPEN
ADAPTER CABLE

FIGURE 3-4

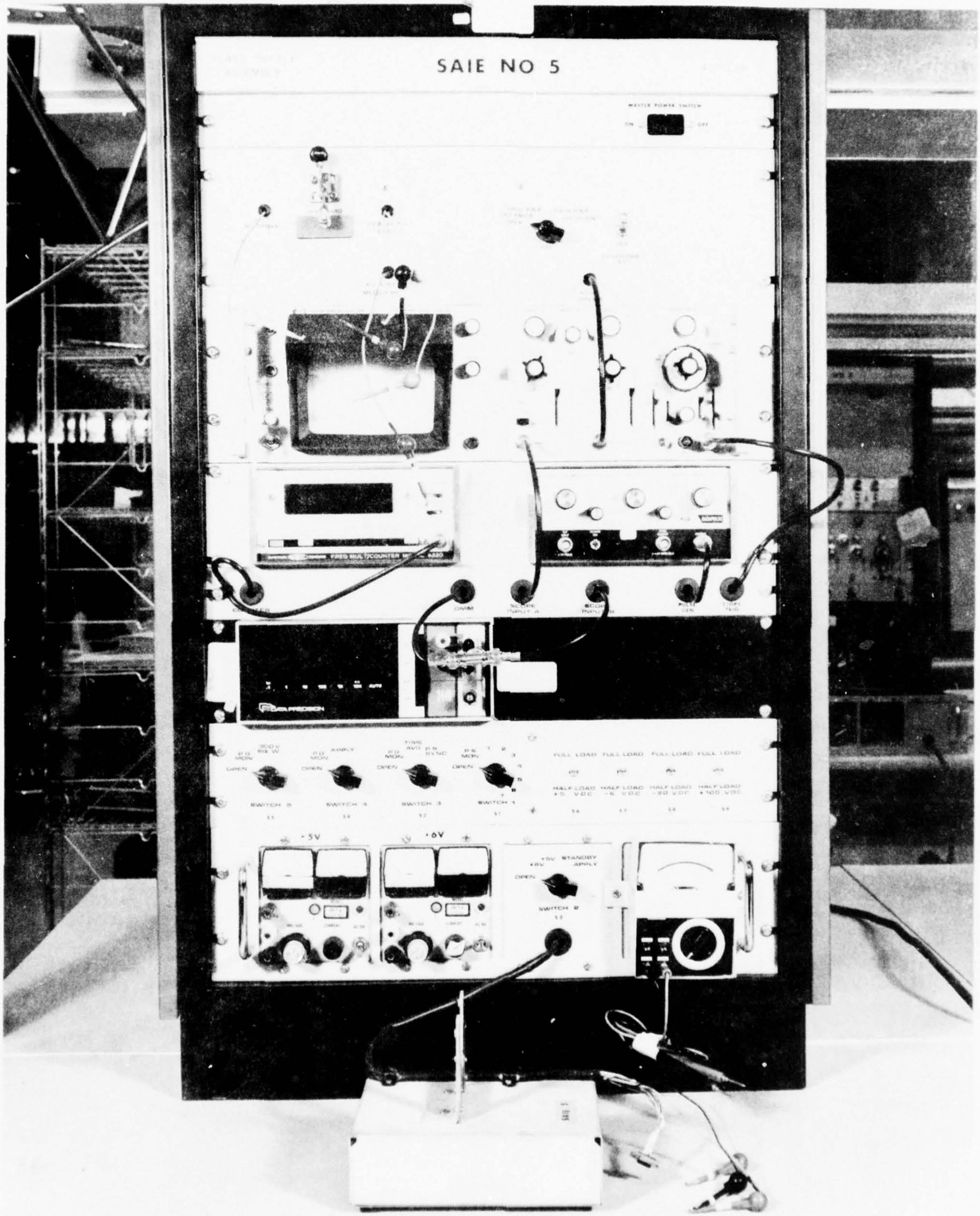

SAIE NO 5
MASTER POWER SWITCH
ON
OFF
FREQ MULT/COUNTER
DATA PRECISION
SCOPE INPUT A
FULL LOAD
HALF LOAD
+5 VDC
SWITCH 5
SWITCH 4
SWITCH 3
SWITCH 1
OPEN
+5V
+6V
STANDBY
APPLY
SWITCH 2

FIGURE 3-5

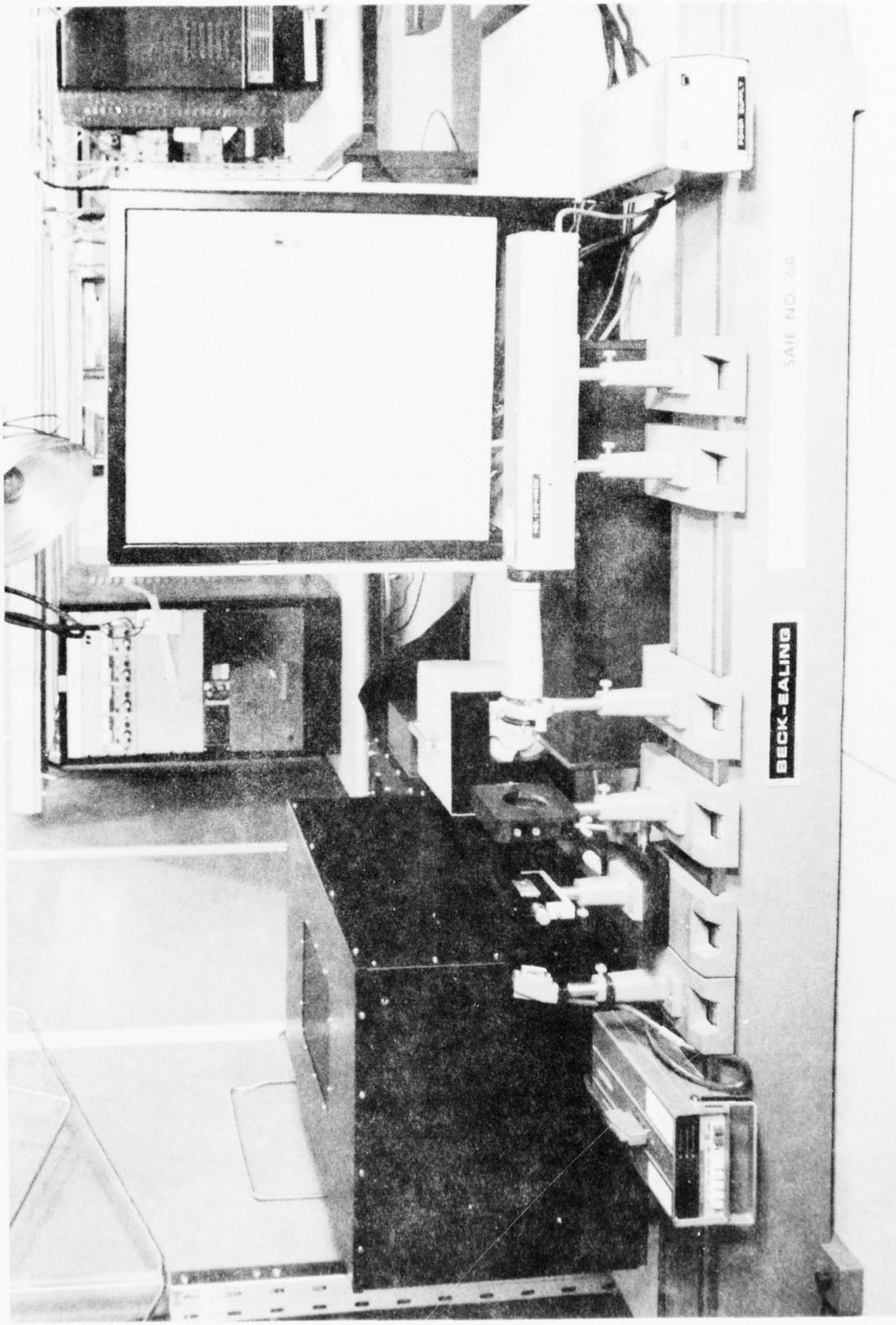


FIGURE 3-6

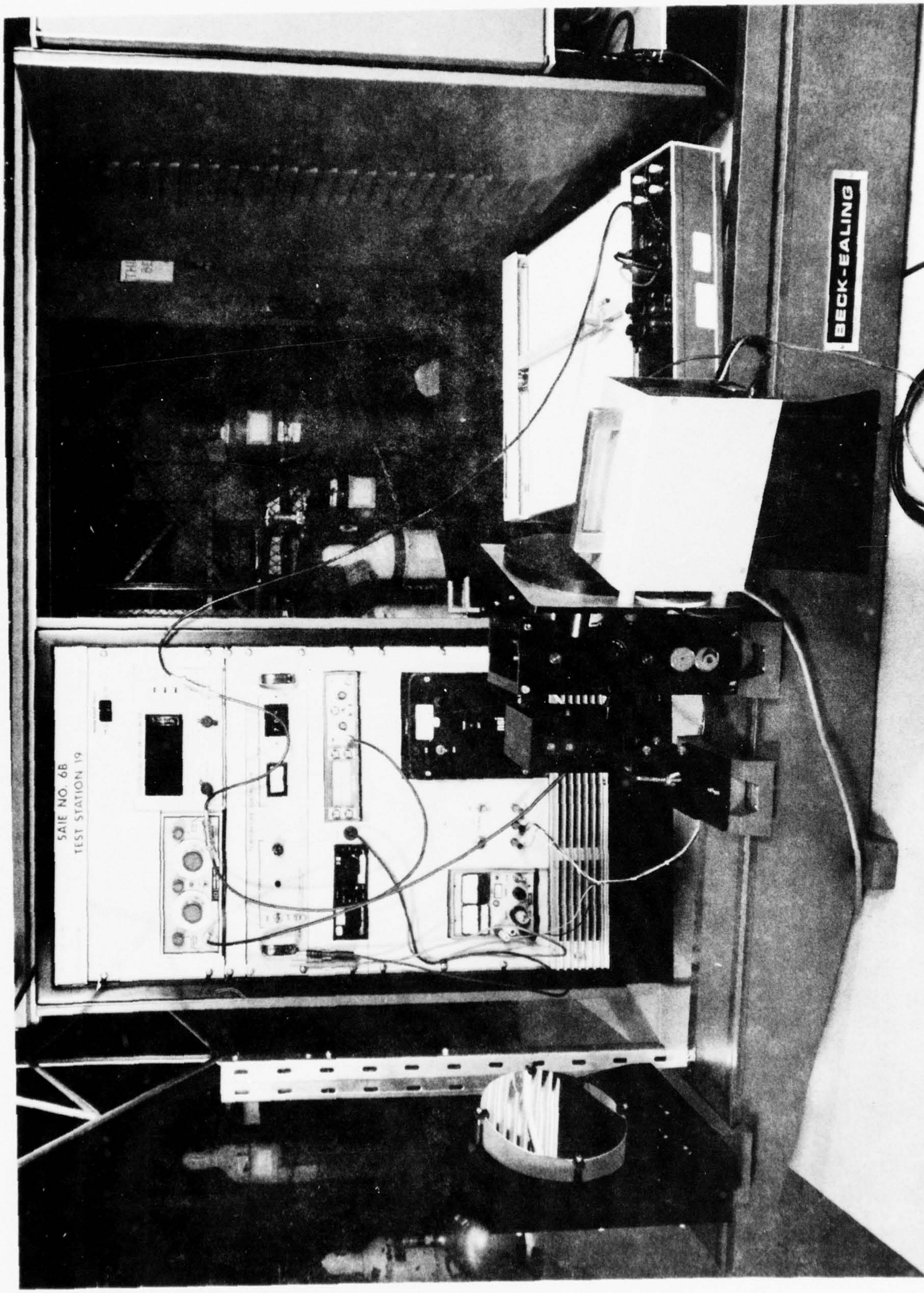


FIGURE 3-7

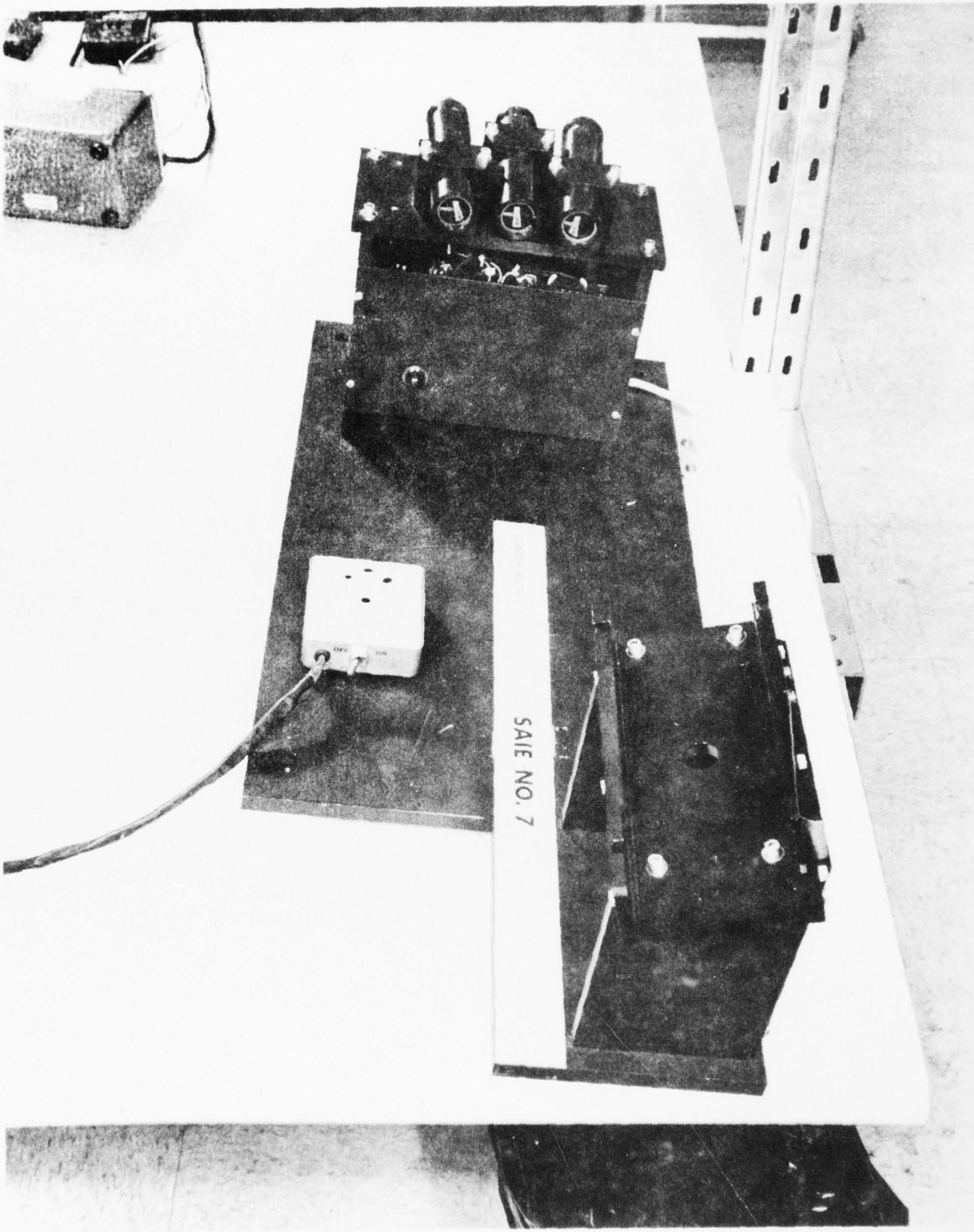


FIGURE 3-8

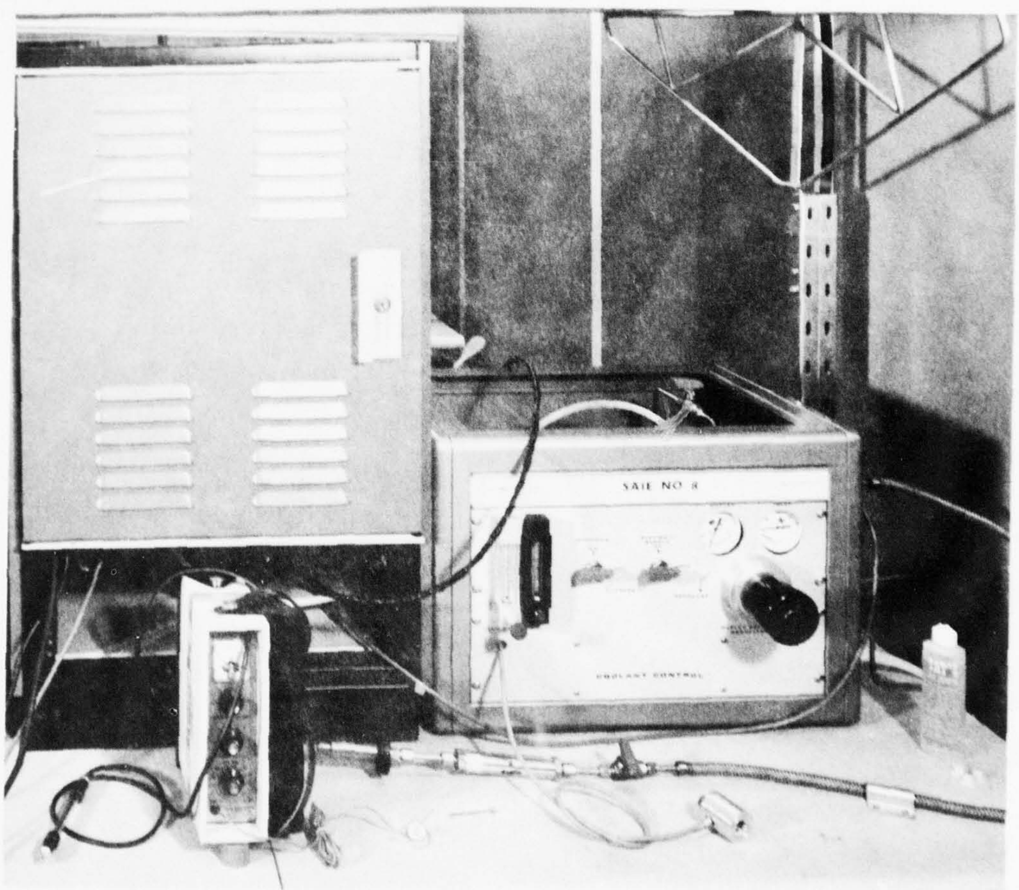


FIGURE 3-9

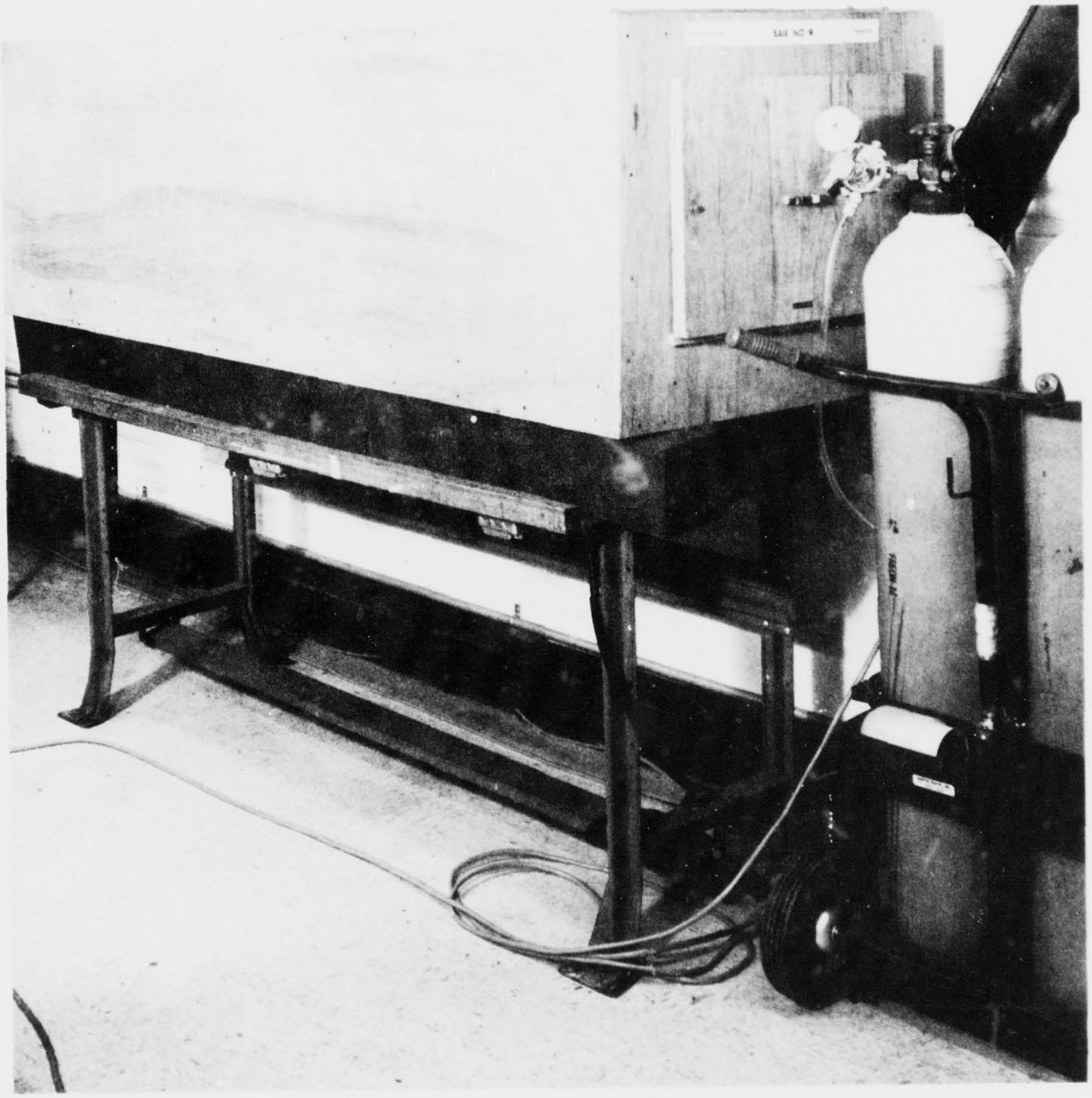


FIGURE 3-10

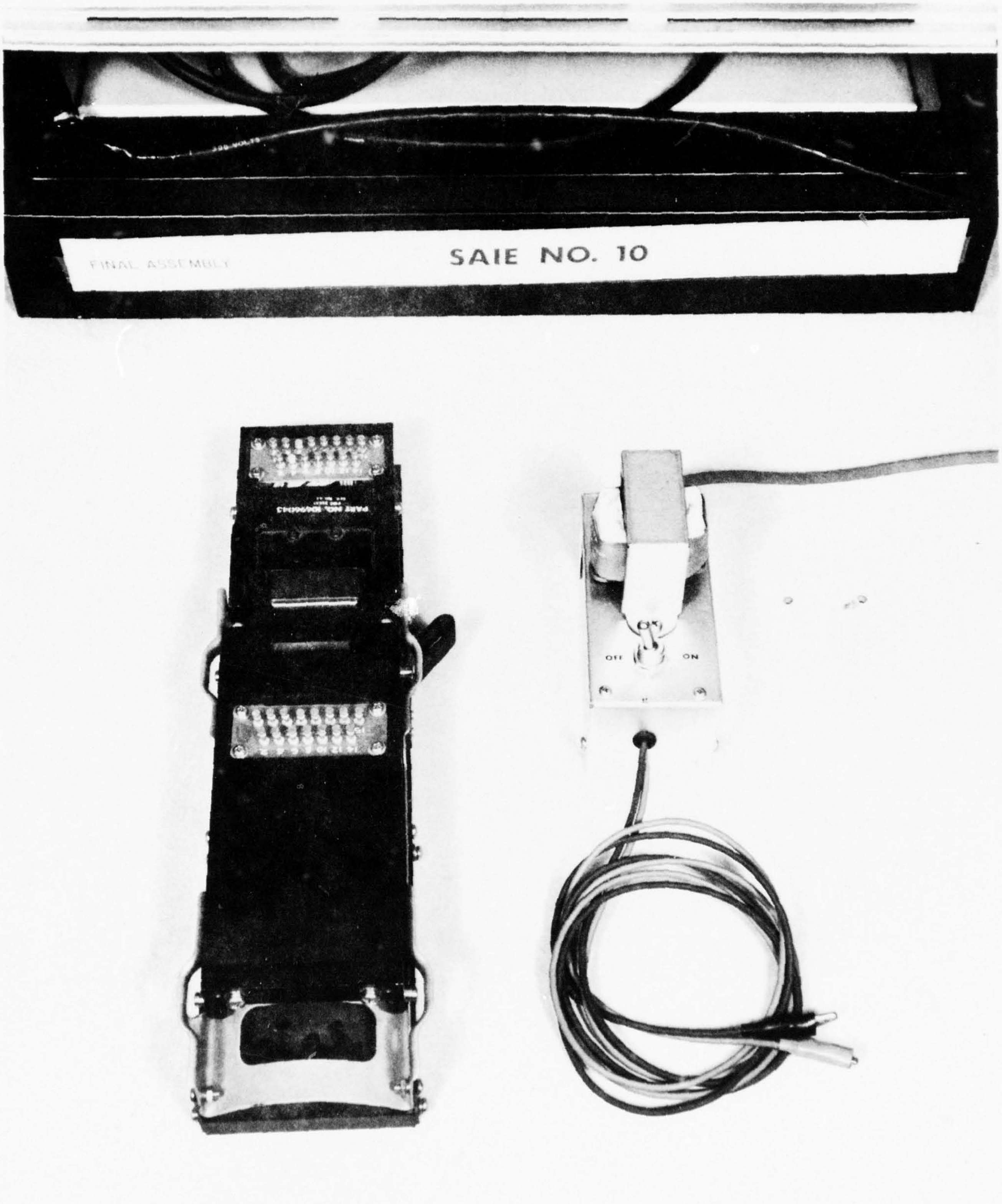


FIGURE 3-11

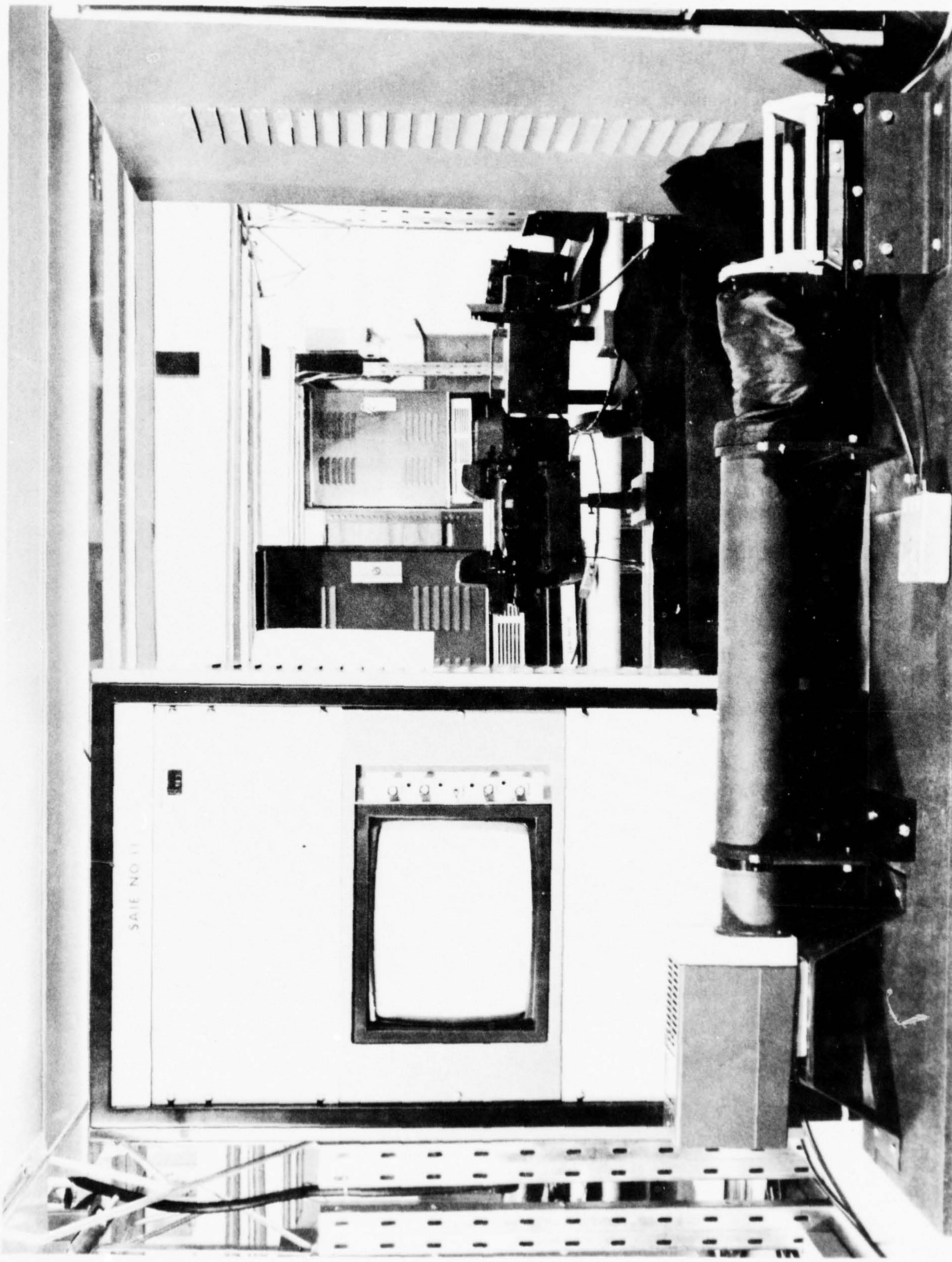


FIGURE 3-12

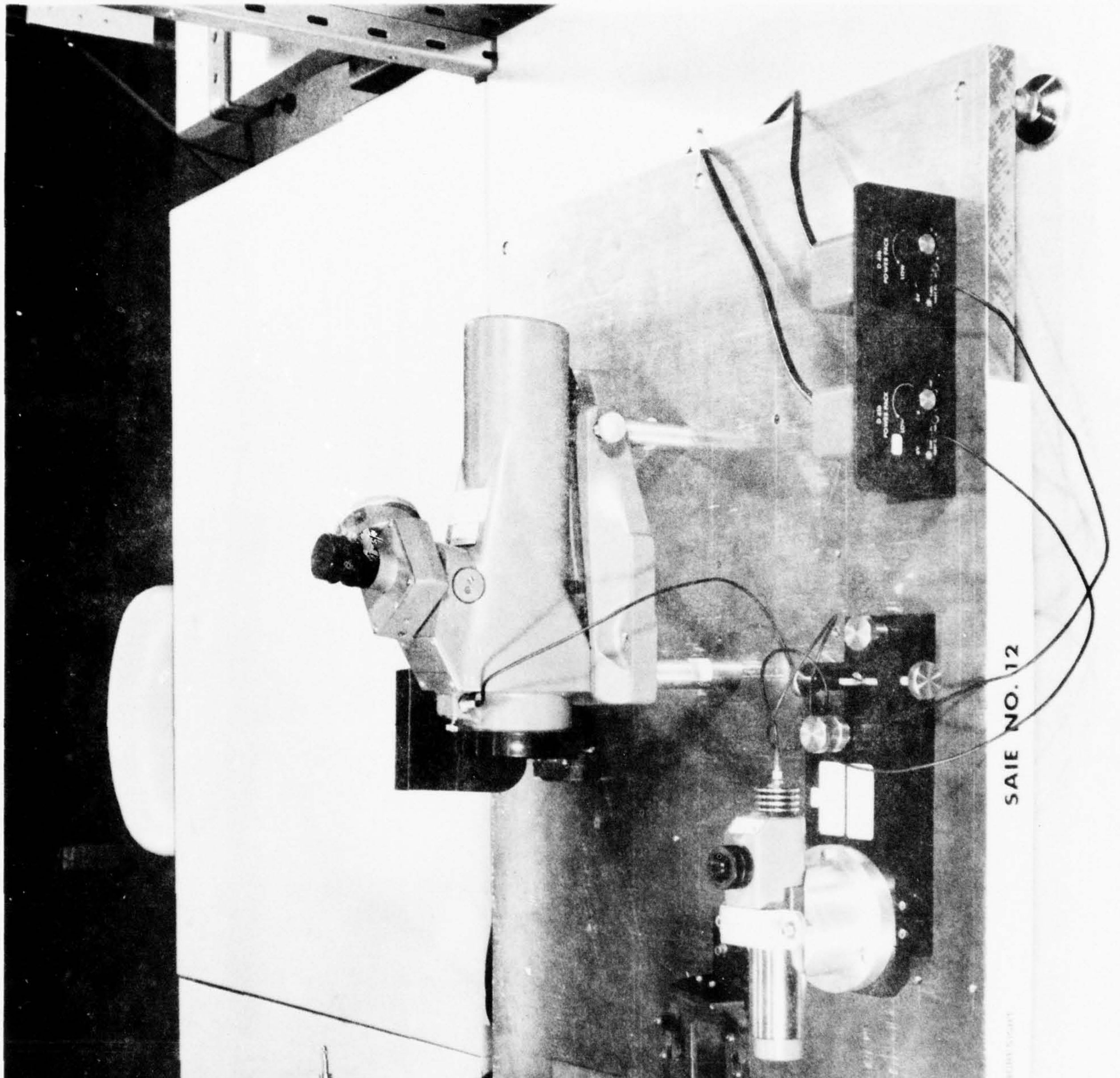


FIGURE 3-13

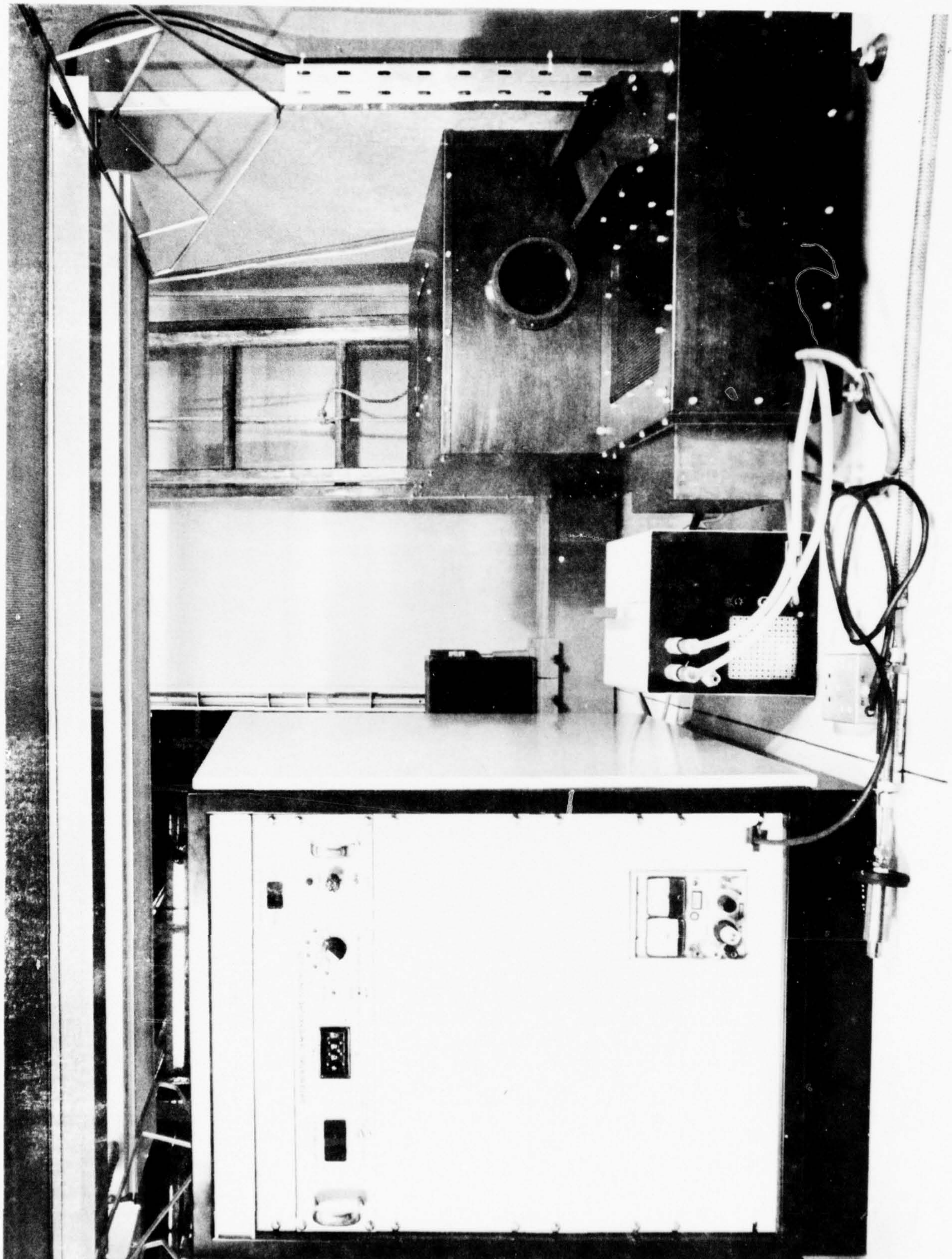


FIGURE 3-14

SECTION IV

DETECTOR APE

4.1 DETECTOR APE

To comply with contractual requirements for pilot line facilities, PAVSC solicited proposals from Santa Barbara Research Center (SBRC) and Optoelectronics Corp., for APE programs on the DRAGON 64 element PbSe detector. Proposals were received from both companies in early 1973. About this same time, however, Optoelectronics had encountered technical problems in fabrication of detectors and was unable to deliver acceptable detectors for the ED programs (see para. 2.2.1). Therefore PAVSC entered into negotiations with SBRC for a detector/ cryostat APE program during May 1973.

Negotiations and preparation of procurement documents continued until June 1973 at which time the government placed a hold on all APE subcontracts. The hold was initially intended to be for a 30 day period and PAVSC continued discussions with SBRC. However, the hold continued beyond the initial period and in November 1973 SBRC notified PAVSC that they would expend no additional effort on the detector APE negotiations until a firm award date was established. At this time all effort with SBRC ceased. In early January 1974 PAVSC received verbal authorization from the government to proceed with subcontracts.

PAVSC had notified the government that because of the approximate six month delay in the release of the detector APE program it was necessary to procure additional detectors, that would not be fabricated on the SBRC APE pilot line, in order to meet the fabrication schedule for the AN/TAS-3 APE models.

Negotiations were completed with SBRC and they were authorized to proceed with the detector APE program in March 1974. In addition, as a result of Contract Modification P0001 SBRC was authorized to proceed in April 1974, on the fabrication of a detector/cryostat SAIE test set and eight additional detectors. Contract Modification P0006 subsequently reduced the number of additional detectors from eight to four.

The SBRC APE pilot line was completed in September 1974 and the first two validation detectors and cryostats were shipped to PAVSC in December 1974. The remaining two APE detectors were kept at SBRC for environmental qualification testing.

Vendor delays in the delivery of a data acquisition system and the cryogenic compressor to SBRC caused the completion of the SAIE test station to be delayed until March 1975.

Environmental qualification testing of the detector/cryostat was started and completed in April 1975. During the environmental testing the SAIE test station was used to perform baseline and functional tests on the detector and cryostat.

All environmental tests were successfully completed with the exception of one failure which occured during vibration testing of the detector. Three detector element leads were determined to be open. During a PAVSC visit to SBRC in May 1975 this detector was opened to visually examine the internal structure and the failed leads. Examination revealed that all three leads were broken just into or adjacent to the weld at the sunburst. This is the point where the 2 mil wires from the conductive stripping are welded to the sunburst.

SBRC indicated that welding workmanship was the cause and corrective action on any future units will consist of improved operation and inspector training. It should be noted that no detector failures occurred during vibration testing of the APE AN/TAS-3 units. All SBRC effort was completed in August 1975.

4.2 SBRC DOCUMENTS

Included as appendices to this report are the SBRC documents listed below. These documents were prepared as part of the SBRC APE program requirements.

Appendix B - Volume I - SBRC Final Production Plan

Appendix C - SBRC SAIE Operation and Calibration Manual.

SECTION V

TEST RESULTS

5.1 GENERAL

Testing during the APE program was divided into three general categories; sub-assembly, system and environmental test. All testing was performed in accordance with contractual and MIL.-Q-9858 requirements. Testing was monitored by Quality Assurance by periodic audit of the testing and review of all data. In some cases, tests were jointly performed by QA and Engineering. Laboratory system test was performed on SAIE equipment which was developed on the APE program. SAIE test equipment was verified by government witness of SAIE Verification Test performed in accordance with contractual requirements.

5.2 LABORATORY SYSTEM TEST

A tabulation of significant system test results is presented in Table 5-1. All units complied with the test requirements.

5.3 ENVIRONMENTAL TESTS

5.3.1 SCOPE AND SUMMARY

The environmental tests for the Night Vision Sights fabricated under Contract DAAK02-73-C-0047 were performed during the period of September 27, 1974, to November 13, 1974. Two systems were used for the environmental program, serial numbers 30 and 31. All tests were performed in accordance with and as detailed in the approved test plan, GSDR No. 714.

TABLE 5-1

LABORATORY SYSTEM TEST AN/TAS-3 (APE MODEL)

C162302 01000000A REQ PARA.	TEST PARA.	PARAMETER	SPECIFICATION REQUIREMENT			TYPICAL READINGS BY SERIAL NUMBER 30	31	32	33
3.2.1.1	4.2.2.3	FIELD OF VIEW (1)	HORIZONTAL	6° ±5%		6°	6°	6°	6°
			VERTICAL	4° ±5%		4°	4°	4°	4°
3.2.1.2	4.2.2.4	MINIMUM RESOLVABLE TEMPERATURE (2)	CYC/MR	MRT (°C)					
			.1	.14		.02°	≤.14	≤.14	≤.14
			.3	.2		.04°	≤.2	≤.2	≤.2
			.5	.57		.07°	≤.57	≤.57	≤.57
			.7	2.7		.12°	≤2.7	≤2.7	≤2.7
			.8	7.2		.23	≤7.2	≤7.2	≤7.2
3.2.1.3.1	4.2.2.5	BORESIGHT ALIGNMENT	±0.5 mr			0.28	0.0	0.0	0.15
3.2.1.3.2	4.2.2.6	BORESIGHT RETENTION	±0.5 mr			0.0	0.13	0.13	0.0
3.2.1.11	4.2.2.1.5	FOCUS (3)	400 ±20 METERS			400	400	400	400
3.2.1.17	4.2.2.2.1	AUDIBLE NOISE	FREQUENCY (HZ) CENTER	FREQUENCY (HZ) OCTAVE BAND	CORRECTED MAX. SOUND LEVEL DB re. 0002 μ bars				
			125	87- 175	54	24.9	38.6	32.2	36.4
			250	175- 350	53	27.0	24.9	26.0	27.2
			500	350- 700	48	12.8	17.0	17.2	14.0
			1000	700- 1400	40	13.9	17.6	17.9	18.9
			2000	1400- 2800	34	19.9	10.0	19.9	19.9
			4000	2800- 5600	34	21.1	20.9	20.9	21.0
			8000	5600-11200	31	19.0	16.0	14.8	17.0

FOOTNOTES

(1) FIELD OF VIEW ADJUSTED TO PRECISE SPECIFICATION REQUIREMENT AT TIME OF TEST.
(2) MRT TESTS ON UNITS SUBSEQUENT TO S/N 30 WERE PERFORMED USING GO, NO-GO TECHNIQUES ON SAIE 13. THESE UNITS MET THE REQUIREMENT WITH NO DIFFICULTY. IT MAY BE ASSUMED THAT THE ACTUAL MRT'S WERE MORE IN KEEPING WITH ORDER OF MAGNITUDE OF S/N 30; HOWEVER, SINCE THE ACTUAL MRT IS NOT RECORDED THE DATA IS ACCORDINGLY PRESENTED AS EQUAL TO OR LESS THAN THE SPECIFICATION REQUIREMENT.
(3) THE UNITS WERE FOCUSED ON AN OPTICAL BENCH USING A SOURCE AND A COLLIMATING MIRROR; WITHIN ±0.1 CM OF THE COLLIMATOR OFF-AXIS MIRROR FOCAL POINT.

At the conclusion of the impact shock test, it was observed that the mounting bracket support for the tracker mating connector had loosened. A review was made and it was determined that the condition was most likely a result of prior insertions and not a direct result of the shock test. However, this condition was undesirable and design changes were incorporated to strengthen and provide additional support for the connector mounting bracket. ECO's 23585-0179 and 23585-0180 detail these changes.

Internal inspection of the unit after the impact shock test, revealed some deformation of the Angle Bracket and Plate used as hinge supports for the Display Card, SM-D-649106. There was no effect on system operation, but it was deemed desirable to improve the Bracket and Plate. ECO 23585-0192 increases the strength of these parts by a material change from aluminum alloy 2024-T3 and 5052-H32 to corrosion resistant steel, CRES 302.

System inspection, upon completion of the loose cargo bounce test, revealed the cover for the battery/cartridge storage compartment in the carrying bag had opened allowing partial ejection of the battery and cartridge. While not causing any damage and having no effect on system performance, it was decided to correct this condition. Accordingly, the design of the compartment cover and striker was changed to provide more positive retention of the battery and cartridge. ECO 23585-0184 details these changes.

The impact shock and the loose carge bounce tests were repeated after incorporation of the changes noted. Test results validated the design changes.

5.3.2 ENVIRONMENTAL TEST RESULTS

The environmental tests are listed in Table 5-2, which includes the applicable specification, test location, data completed, and results. When noteworthy problems or circumstances were encountered during testing, the area of interest and condition are listed in the remarks column.

5.3.3 CONCLUSIONS

Results of the environmental tests on the DRAGON Night Sight APE Models, demonstrate compliance with and successful completion of the corresponding requirements and tests of Section J 13 of Contract DAAK02-73-C-0047.

TABLE 5-2

ENVIRONMENTAL TEST RESULTS

TEST	MIL STD 810 B METHOD-PROC	PERFORMED ON SYSTEM	COMPLETED	RESULTS	REMARKS
Immersion	512 I	31	9-27-74	Passed	Mission operation configuration. Under 3 feet of water for 2 hours. Water temperature 64° ±10°F. Unit temperature 80° ±5°F above water temperature.
Temperature Shock	503 I	30	9-27-74	Passed	Unit in transit drum. Four hours at +155°F, to -65°F within 5 minutes, hold for four hours = one cycle. Repeat for a total of three cycles.
Impact Shock #1	GSDR 714 Para. 3.2	30	9-30-74	Passed	Unit in carrying bag; 18 shocks, 70g, 10 ms. Unit operated normally after test. Tracker mating connector support bracket loose. ECO 23585-0179 and 23585-0180. During internal inspection, deformation of video board support bracket was noticed, but could not be determined whether they were bent during installation or as a result of the test. Will be checked during retest to validate support bracket improvement.

TABLE 5-2
(Con't)

TEST	MIL STD 810 B METHOD-PROC	PERFORMED ON SYSTEM	COMPLETED	RESULTS	REMARKS
EMI	MIL STD-461/462 Method RE02 & RS03	31	10-3-74	Passed	No detectable emission 14KHz to 1GHz. No susceptibility indications when subjected to: 10 V/M 14KHz - 2MHz 50 V/M 2MHz - 75MHz 10 V/M 75MHz - 10GHz
Loose Cargo Bounce #1	514 XI Pt. 2	31	10-10-74	Passed	Unit in carrying bag, 1/2 hr./face at 284 ±2 RPM. Unit operated normally after test. No damage to unit either internal or external. Cover to battery/cartridge compartment opened. ECO 23585-0184.
Vibration	514 VIII W	30	10-17-74	Passed	Unit in carrying bag. One inch displacement 5-9Hz; 4 g, 9-500Hz; 2 hours/axis.
Loose Cargo Bounce #2	514 XI Pt. 2	---	10-23-75	Passed	Repeat of test previously run on 10/10/74, to validate battery/cartridge compartment cover and latch changes. Mock-up unit used. Compartment cover remained securely latched throughout test.

TABLE 5-2
(Con't)

TEST	MIL STD 810 B METHOD-PROC	PERFORMED ON SYSTEM	COMPLETED	RESULTS	REMARKS
Impact Shock #2	GSDR 714 Para. 3.2	31	10-24-75	Passed	Repeat of test previously run on 9/30/74, to validate tracker mating connector bracket improvements. Inspection of the unit upon completion of the test revealed no looseness of the tracker mating connector support bracket. Internal inspection revealed video board support brackets deformed as in Test #1. ECO 23585-0192 incorporates a stronger bracket material.
Impact Shock #3	GSDR 714 Para. 3.2	31	11-13-74	Passed	Repeat of tests previously run 9-30-74 and 10-24-74; to validate improved bracket and plate design using stronger material. No deformation noted.

TEST LOCATION: All tests, with the exception of EMI were performed at:

York Research Corporation
One Research Drive
Stamford, Connecticut 06904

EMI: AEL Service Corporation
Monmouth County Airport
Route 34
Wall Township, New Jersey

SECTION VI

CONCLUSION

6.1 GENERAL

This APE program has resulted in the fabrication of four production engineered models of the AN/TAS-3 and the development of a pilot production line. All tooling and test equipment necessary to support production at a 20 unit per month rate, on a single shift has been fabricated. A 60 per month rate can be attained by the addition of redundant tooling and test equipment, in the limiting areas, such as noted in the SBRC Final Production Plan (Appendix C).

The units produced are a production model of a light weight, reliable and rugged passive infrared real time imaging night vision sight for use with the Guided Missile System Surface Attack (DRAGON).

6.2 APE MODEL AN/TAS-3

Four APE model AN/TAS-3 units were fabricated from the pilot line tooling and manufacturing procedures described in the Final Production Plan (GSDR No. 815). These units, which contained the producibility changes and improvements described in Section II, were subjected to the required environmental test and successfully passed these tests. During test, some problems were encountered (refer to Section V) with brackets on the night sight and the carrying bag. Corrective action was taken in these areas and the tests repeated to validate the changes.

6.3 RESULTS

This program has demonstrated that advanced production engineering can be successfully implemented in parallel with the latter phases of engineering development. Production engineering of the AN/TAS-3 was performed during the field test cycle of the ED program and in all cases production versions

of modifications necessary to correct field deficiencies were incorporated into the APE models. In some instances where it was not practical to modify the ED units to correct a deficiency, such as EMI, the modifications were developed in the APE program and installed in the APE units only.

If the APE program had not been placed approximately twelve months would have been added to the production lead time for the AN/TAS-3 resulting in a twenty five month lead time to the start of delivery in lieu of the thirteen months forecasted.

PAVSC believes that the existing APE model of the AN/TAS-3 meets all the requirements for a Night Sight for the DRAGON missile system' however, significant improvements can be made. These improvements are discussed in Section VII, Recommendations.

SECTION VII

Recommendations

7.1 GENERAL

At the conclusion of the AN/TAS-3 Engineering Development program, under Contract DAAK02-72-C-0156, PAVSC presented a set of recommendations for the AN/TAS-3 that will afford significant operational and logistics improvements. Events have not altered the validity of these recommendations and they are therefore also presented in this report.

Based on experience gained during development and testing of the AN/TAS-3, PAVSC recommends that four major areas of improvement to the existing design be considered. They are:

Thermoelectric (TE) Cooling	- Para. 7.2
Image Improvement	- Para. 7.3
Extended Range Optics	- Para. 7.4
Dedicated TOW Sight	- Para. 7.5

Additionally, upgrading for the existing AN/TAS-3 ED model Night Sights and improvements to ancillary equipment are recommended as follows:

Existing AN/TAS-3 NVS	- Para. 7.6
Battery Charger	- Para. 7.7
Launch Blast Simulator	- Para. 7.8
Carrying Bag	- Para. 7.9

Each of the preceding items is briefly discussed in the indicated paragraphs.

7.2 CONVERSION TO THERMOELECTRIC COOLING

A factor that adds cost and delay to the development of night vision equipment is the choice of method for cooling infrared detectors to cyrogenic temperatures. Cooling may be accomplished by one of three methods:

a. Thermoelectric cooling
b. Bottle cooling by liquefied or pressurized gas
c. Closed cycle coolers.

Contributing to the complexity of the cooling problem is the need to modularize new equipment designs so that commonality of components (to a varying degree for each equipment) can yield benefits in reduced costs, simplified logistic support, and orderly technological growth.

There are enough performance data on the various methods used for cooling detectors in thermal imaging systems for Army applications that the optimum cooling method for each particular application has become evident. Applications may be divided into four broad categories:

(a) Thermal weapon sights or viewers operated by the foot soldier.

(b) Thermal weapon sights or viewers for driving aids on lightweight and thin skinned vehicles; such as jeeps, trucks, ARSV and MICV.

(c) Thermal weapon sights and viewers for heavy vehicles; such as the M-60 and XM-1 Tanks.

(d) Thermal weapon sights and viewers for fixed wing and helicopter aircraft.

For the first category, the design and performance requirements are imposed by the individual infantryman who must carry his weapons and who cannot be readily supported or resupplied under fire. His life depends on his ability as a basic combat element to perform his function.

Accordingly, thermal weapon sights for the foot-soldier must be lightweight, capable of operating after prolonged exposure to dirt and moisture, and must be simple to support. Thermoelectric cooling is the only feasible cooling method for these applications.

The reliability of thermoelectrical cooling and the (acceptable) operational range achievable with 3 - 5 micrometer systems, far outweigh the additional range performance that could be obtained with a gas bottle cooled 8 - 14 micrometer system.

In the following paragraphs the disadvantages of the gas bottle approach as well as the advantages of the thermoelectric cooling approach will be detailed.

Disadvantages of the Gas Bottle Cooler for the DRAGON Night Sight are:

1. With two consumables (battery power and gas pressure) the rate of consumption is in general, not equal. The rate of consumption depends upon usage (cycling time and number of start-ups) and environmental conditions (temperature).

2. The operator has no reliable way to determine the status of his consumables. Status indicators must be readable in total darkness, add little or no weight, and must be inexpensive and reliable. Practical indicators of this type do not exist and, until developed, constitute a major objection.

3. When the pressure runs low, the gas bottle must be changed. This operation must frequently be performed at night with Arctic gloves or in the battlefield under fire. The possibility of contaminating the gas lines during the bottle change requires that an in-line molecular filter located close to the cryostat be included. Like the bottle, this filter must be changed when its useful life has expired. The useful life expectancy of the filter is unpredictable. Changing of the filters can be difficult and awkward under field combat conditions, particularly at night.

4. Gas bottles as part of a night sight inherently represent a hazard to the foot soldier since they are pressurized at 3000 to 6000 psi. A fragment striking the gas bottle could prove lethal to the gunner even though it did not hit him directly.

5. Gas bottles and fill station equipment as well as the gas for refilling the bottles represent new items for an already overburdened Army inventory system.

   U.S. Navy history with nitrogen cryogenic bottle refills on aircraft carriers indicates that the bottle remained an unsatisfactorily resolved problem aboard aircraft carriers. The problem of refilling gas bottles under field combat conditions is expected to be much greater than aboard ship. Sophisticated field charging stations are necessary to provide gas bottle refills.

6. The level of skill required by night sight operations demands more training for gas bottles than for thermoelectric cooling. Additionally, special training is required for charging station attendants, who perform no other function in combat.

The continuing need to refill these bottles and replace filters represent a mounting cost for the entire life cycle of the equipment.

7. Because high pressure bottles are necessary, the present technology shows little promise of achieving a low-cost expendable bottle; for example, projected price for initial procurement of high pressure bottles are approximately $25 each in quantities of 10,000 or $100 each in quantities of 100. To this must be added the refilling costs.

8. Gas bottles have a limited refilling lifetime. In order not to exceed this, the bottles must be marked at each refilling. The vulnerability of a defense, depending upon a gas stock pile and gas charging stations is considerable since the destruction of the station could neutralize the NW capability of entire force depending upon it for supply.

Advantages of Thermoelectric Cooling for the DRAGON Night Sight are:

1. Energy consumed by the thermoelectrically cooled night sight is from a single source, the same battery that is used to operate the electronics.

2. Only spare batteries need be carried by the gunner or supply support activity.

3. The thermoelectrically cooled unit is lighter in weight than the gas bottle cooled unit.

4. The thermoelectrically cooled unit is of higher reliability.

   a. It does not suffer freeze ups
   b. There are no moving parts
   c. Thermoelectric cooling is all solid state.

5. No additional training is required for handling or refilling bottles.

6. No additional items are introduced into Army inventory (no filters, gas bottles, or fill stations).

7. A force using thermoelectrically cooled sights cannot be neutralized by destroying a bottle fill station or a gas stockpile.

8. There is no additional hazard to the gunner which might result from gas bottle pressure.

9. Theremoelectrically cooled night sights will operate uninterruptedly for the life of the battery.

10. A lower demand for personnel skill is required.

11. Theremoelectric cooling has proved field experience. The HHV using thermoelectric cooling has been successfully used in Viet Nam and in operational tests at Ft. Bragg.

12. When the total cost of ownership over the life cycle of the equipment is considered, the thermoelectrically cooled systems represent only their first cost. The bottle cooling systems represent continuing re-supply costs, more components to be added to inventory, cost of filling stations and the labor to operate those stations.

13. To conserve battery use, night sight operation from power supplied by Army vehicles can be provided.

PAVSC strongly recommends that night vision applications requiring moderate system resolution for ranges out to 2000 meters be covered with 3 - 5 micron thermoelectrically cooled equipments. Near future improved system performance appears to be available through recent advances in TE cooler materials and fabrication techniques as well as through new and improved detector materials, better application of available detector performance capability, cold filtering and other techniques. Considering the operational advantages, the available performance growth potential and the expected lower cost of the thermoelectrically cooled approach it appears highly desirable to develop a family of low to medium performance systems using standard modules.

Therefore, it is recommended that the AN/TAS-3 be converted to thermoelectric cooling and that as an interim step, the existing ED units be modified to TE (see paragraph 7.6).

7.3 IMAGE IMPROVEMENT

The DRAGON Night Vision Sight (NVS) signal processing has been designed to combine high sensitivity with fast overload recovery. This was done to optimize the image from weak targets at maximum weapon range. The combination of these design characteristics has resulted in a signal dynamic range of 25-30 dB which is sufficient for low contrast targets but results in a image from high contrast targets, such as vehicles at close range, that have a definite white on black appearance with loss of grey scale.

Other criticisms of the NVS image have been directed toward raster flicker, perceptive line structure and low brightness.

A number of improvements to enhance image quality have been devised and tested in various PAVSC Thermal Imaging systems. These improvements are discussed in the following paragraphs as set forth in Table 7-1 noting that these image problems are not entirely separable--improving one characteristic may or may not affect others.

TABLE 7-1

IMAGE IMPROVEMENT TECHNIQUES

7.3.1 Preamplifier Signal Processing

- a. Overload Recovery
- b. Preamplifier Gains
- c. Preamplifier Bandwidth
- d. High Frequency Compensation

7.3.2 Multiplexer and Video Signal Processing

- a. Improved Multiplexer
- b. Multiplexer Rate
- c. Interchannel Blanking

7.3.3 Display

- a. CRT Phosphor
- b. Image Flicker
- c. Increased frame rate

7.3.4 Quasi-Interlace

7.3.1 PREAMPLIFIER SIGNAL PROCESSING

a. Overload Recovery - A fast overload recovery circuit is incorporated into the AN/TAS-3 preamplifier. This allows fast recovery from saturation due to extremely hot flashes such as is experienced at the moment of missile launch and ensuing launch tube afterburn. This overload recovery circuit, a form of signal limiter, is one cause of dynamic range loss. The preamplifier noise output level is typically 10-15 millivolts p-p and the limited output level is typically 300-400 millivolts. Dynamic range therefore, varies from 40 to 20. On an experimental basis with limiting removed, the preamplifier output level has been measured at over 4 volts p-p resulting in a 20 dB improvement in dynamic range and a corresponding improvement in scene grey scale rendition. With this limiting removed, laboratory tests to simulate launch blast were conducted and no significant increase in recovery time was noted. On two systems, the Vehicle Austere Night Sight (VANS) a system incorporating NVS signal processing, and a thermoelectrically cooled version of the NVS with an extended range lens, the limiting level of the recovery circuit was raised by a factor of 4. This modification was installed along with a reduction of preamplifier gain increasing the dynamic range to about 45 dB. The VANS underwent a series of field test firings with the 105 mm rifle, 20 mm cannon and 50 cal machine gun. No excessive overload was noticed and scene grey scale was noticeably enhanced. The extended range TE cooled system was not exposed to field test firings although recovery time is expected to be the same as in the VANS.

b. Preamplifier Gain - The AN/TAS-3 preamplifier gain of 295 was established to overcome multiplexer noise. This noise exists in the form of switching spikes during which no signal is present at the output. Reducing preamplifier gain does improve the dynamic range (by reducing the preamplifier noise output) but at the expense of S/N ratio. The ability to detect low contrast targets of around 0.1°K delta is decreased and inter-channel dead bands increase in width. A decrease in preamplifier gain must be accompanied by a reduction of multiplexer spikes (see paragragh 7.3.2).

c. Preamplifier Bandwidth - An increase in the upper cut-off frequency of the NVS preamplifiers from 2 kHz to 5 kHz was implemented in the VANS and the TE cooled, extended range NVS. Since the detector noise is essentially 1/f, increasing the upper cut-off frequency will not substantially degrade S/N but will improve the image quality by reason of an increased MTF. Although no comparative data is available, increased bandwidth (along with other image improving modifications) substantially improved picture resolution of small detailed targets.

d. High Frequency Compensation - On the original TE cooled extended range NVS, with the frame rate increased to 20, high frequency peaking was incorporated to extend the high frequency roll-off to about 3 kHz. This modification in conjunction with a reduced preamplifier gain of 150 enhanced image

grey scale and small target detection as observed in various field tests. The effect of higher scan rates and increased high frequency response need to be further evaluated to determine the overall effect on image improvement.

7.3.2 MULTIPLEXER AND VIDEO SIGNAL PROCESSING

a. Improved Multiplexer - Decreasing preamplifier gain (paragraph 7.3.1.b) requires the use of a better multiplexer with a lower level switching spike in order not to lose S/N. On the VANS and the latest version of the TE cooled, extended range NVS a multiplexer with a noise energy output per pulse of 1/5 to 1/10 of the AN/TAS-3 multiplexer was used. The preamplifier gain was reduced by a factor of 2.5 without losing S/N, thereby increasing dynamic range and grey scale rendition.

b. Multiplexer Rate - On the VANS and the improved TE cooled ER/NVS the frame rate was increased to 30. This required a corresponding increase in the vertical scan frequency (and the master clock from 30 kHz to 650 kHz) in order to provide an adequate number of incremental samples and to preserve a merged raster. The preamplifier bandwidth was also increased as discussed in paragraph 7.3.1.c. The improved multiplexer can also handle the corresponding increase in multiplexer switching rate (72 times the vertical scan frequency).

c. Interchannel Blanking - On the AN/TAS-3 multiplexer, switching spikes are removed from the video by a short interchannel blanking pulse fed into the video output stage. On the VANS and on the improved version of the TE cooled ER/NVS the use of the high speed multiplexers with their extremely narrow switching spikes obviated the need for this blanking pulse and it was removed resulting in a more homogeneous display. This is because the scan efficiency goes from 80 percent (not counting retrace) to 100 percent. Further improvement in dynamic range can be achieved by changing a transistor shunt switch on the output of the multiplexer (still required for horizontal cross hair blanking) to a FET switch thereby eliminating clipping of the video signal at this stage. The resulting improvement in cross hair brightness must be weighed against circuit changes required to incorporate this FET.

7.3.3 DISPLAY

a. CRT Phosphors - The AN/TAS-3 uses a CRT with a P20 phosphor. This is a bright yellow-green display (5600Å peak) with a persistence of 0.2 millisecond. Two other CRT's, one with a P28 phosphor and one with a P45 phosphor were evaluated in the laboratory. The P28 phosphor is yellow-green (5500Å peak) with a relatively slow 500 millisecond persistence. It was thought that this slow persistence might tend to reduce the flicker effect but a side-by-side comparison with a standard AN/TAS-3 display revealed an overall degradation of picture quality to an unacceptable level, according to several trained observers.

The P45 phosphor is white with a 1.7 millisecond persistence. A brief evaluation was conducted and relatively favorable comments were received regarding a somewhat reduced level of flicker although more testing is needed on this type of phosphor. The P45 phosphor has been successfully used on two other PAVSC imaging systems and apparently has less phosphor burn-in than the P20 type, an important consideration for the NVS.

b. Image Flicker - As previously stated the present AN/TAS-3 operates at a frame rate of 15 fps. The effective display frame rate seen by the eye may be one half that or 7.5 fps due to two effects.

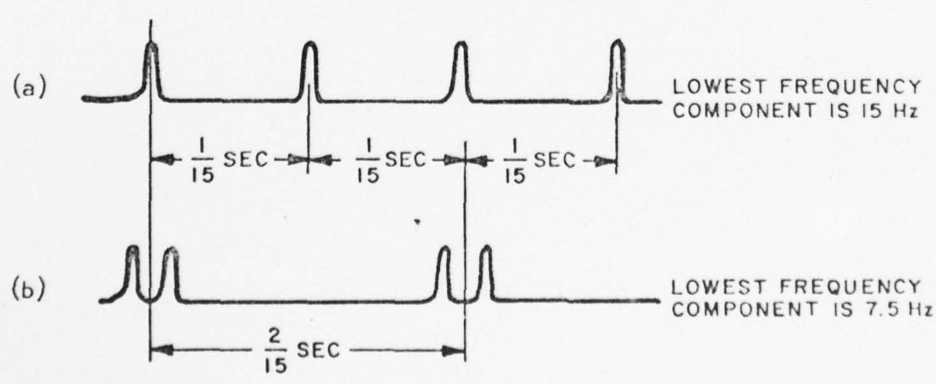
Limited low frequency response of amplifiers.

Edge flicker caused by back and forth scan.

The limited low frequency response on the NVS was purposely chosen so as to provide rapid recovery from strong thermal targets and also to reduce the visibility of the detector 1/f noise. However, the limited low frequency response produces differentiation of the video wave form particularly for extended targets. The image presented on the CRT will therefore be slightly different during the scan from left to right than from right to left.

The eye is particularly sensitive to this and views the two images as different frames and thus in effect, sees a 7.5 fps image.

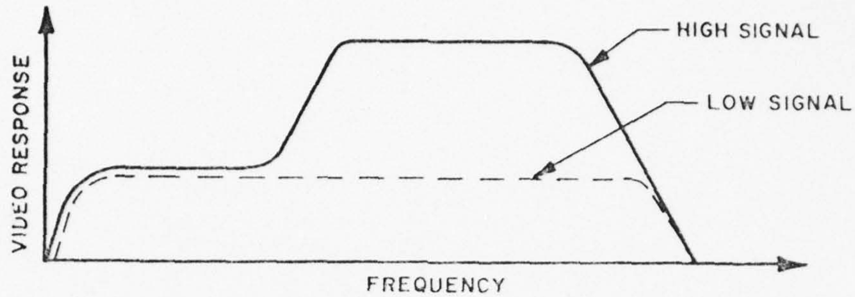
Edge flicker is caused by another effect. This may be explained by considering first a target in the exact center of the field of view and secondly, a target near the edge of the field of view. With the target in the center, the video waveform would appear as shown in (a) and with the target near the edge as in (b).



Of the two flicker producing effects, the edge flicker effect appears to be the lesser.

New signal processing techniques are being investigated on the Common Modules Program that appear to have application to the flicker, recovery and image quality problems of the NVS Specifically, a non linear technique which produces a video response such as is shown in (c) below.

(c)



For weak video signals, the frequency response is extended to very low frequencies and thus will produce nearly identical frames from right to left and from left to right. For very bright extended targets, the video bandpass is reduced in the low frequency end. This helps to improve the recovery. The expected benefit of this technique is that the normal background which contains relatively weak video signals will be seen at the frame rate of the scanner and with less fatigue producing flicker. Strong target visibility will possibly be enhanced since the flicker frequency will be one half that of the scanner.

Another important benefit expected from this technique is the reduction or virtual elimination of black streaking to the right and left of bright targets. This should substantially reduce the obscuration of weak targets near bright targets.

c. Increased frame rate - On the AN/TAS-3, because of AC coupling and the edge flicker effect discussed above, the apparent flicker frequency is equal to one half the frame rate rather than being equal to the frame rate. On the VANS and on the improved TE cooled ER/NVS the scan rate was increased from 15 to 30 frames per second. The higher frame rate does increase the apparent flicker frequency and definitely improves the image quality. The increased scan rate requires changes in the preamplifier and multiplexer as previously discussed.

7.3.4 QUASI-INTERLACE

The present AN/TAS-3 design uses a simple back and forth azimuth scan motion. The scanned area is covered by a linear array consisting of 64 nearly contiguous elements. The array geometry is depicted in Figure 7-1. It will be noted that the inter-element spacing is normally 0.0008 inch and the element size is normally 0.00315 inch. The actual detectors as delivered have an average element spacing closer to the upper tolerance limit of 0.001 inch and an average element size closer to the lower tolerance limit of 0.003 inch. There exists therefore a gap of roughly 33 percent in the scanned area coverage (not counting optics spot blurring).

It is possible by interlacing two successive scan fields to double the number of raster lines in the display (see Figure 7-2). This type of interlace will completely eliminate the 33 percent gap. The interlace will provide some overlap of scanned lines resulting in a more uniform display raster. The higher number of vertical sample points is expected to also improve the vertical MTF.

AD-A051 219 PHILIPS AUDIO VIDEO SYSTEMS CORP MAHWAH NJ GOVERNMEN--ETC F/G 17/5
ADVANCED PRODUCTION ENGINEERING (APE) NIGHT VISION SIGHT INFRAR--ETC(U)
DEC 75 DAAK02-73-C-0047
UNCLASSIFIED GSDR-817A-VOL-1 NL

2 OF 2
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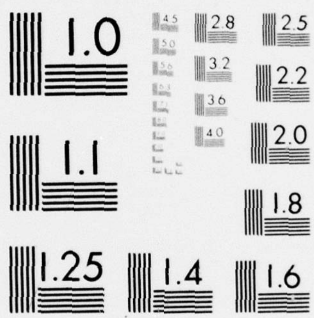
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1.1
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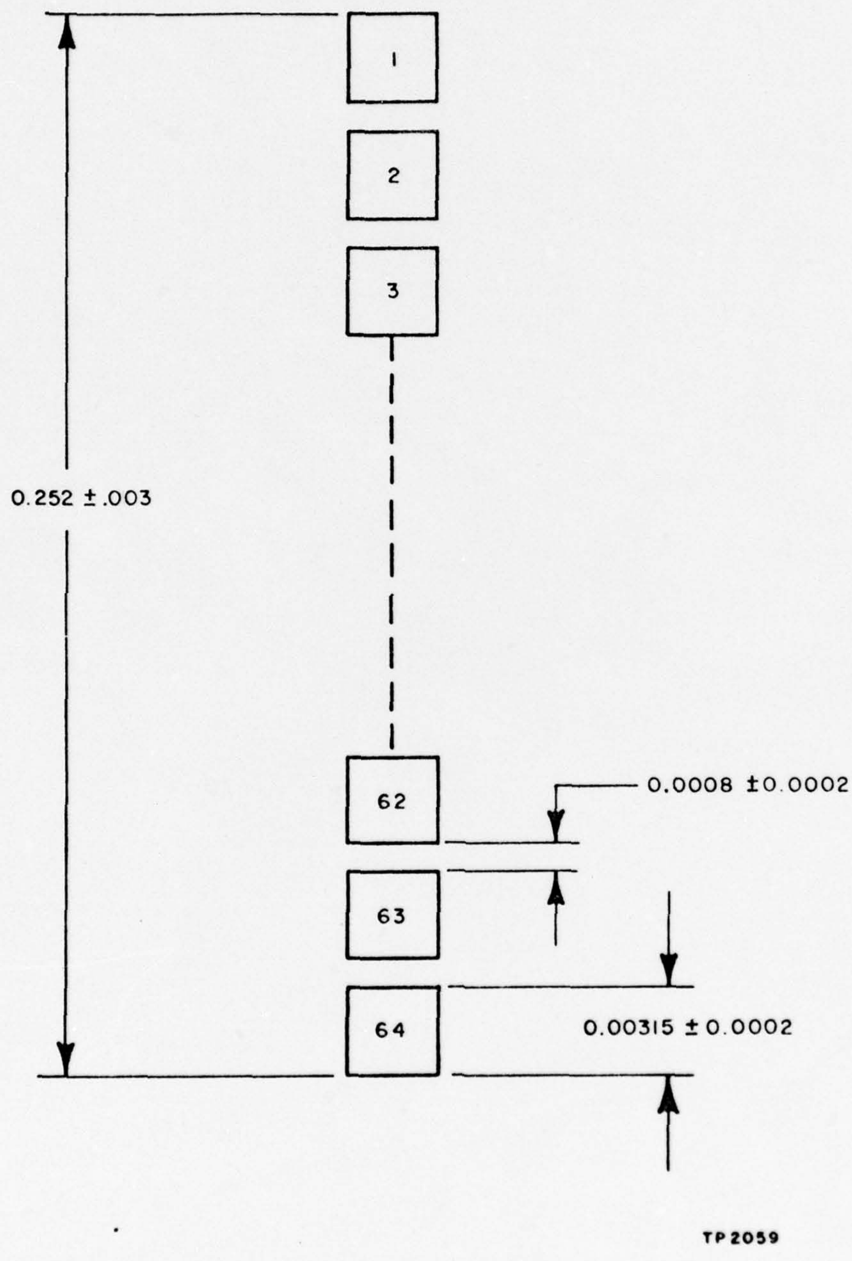


Figure 7-1. NVS Detector Array

Figure 7-2. Interlace Scheme

To achieve these desired improvements PAVSC proposes to investigate two methods for implementing the required interlace scan motion. A preliminary evaluation of the two methods has shown that each can be designed into the existing DRAGON Night Sight package with minimum redesign. The two methods are:

a. Scan Mirror Interlace - Figure 7-3 shows the method of interlacing with the scan mirror. The elevation axis is placed on the optical axis to prevent axial displacement, and hence defocus, with interlace. The interlace drive elements are two push solenoids which are actuated in synchronism with the azimuth scan mirror. The existing bounce/contact springs can be used for solenoid programming. Two adjustable stops are provided to accurately adjust the excursion.

It would be desirable to place the two solenoids on the "short" end of the mirror to provide better balance. However, the drive sector gear is in the way and a symmetrical system is used instead. The existing balance weights on the mirror, therefore, remain the same. Since the added mirror mounting frame and solenoids pushes the center of gravity further away from the azimuth scan axis, the balance weight on the drive shaft is increased to compensate for this shift. Electrical leads to the solenoids are flexible wires of berryllium copper (spring temper) to ensure long life and good flexibility.

The calculated elevation angle movement of the scan mirror is very small amounting to 0.088°. The linear motion at the drive points is only 0.00095 inch. To prevent excessive errors from being introduced at the elevation axis flexure pivots will be used instead of ball bearings, thereby eliminating the possibility of radial play.

b. Wobble Plate Interlace - Figure 7-4 shows the method of interlacing using a refractive wobble plate element. Image displacement is generated by tilting the optical plate in the convergent optical beam. The most convenient location for the optical plate, considering size, inertia, and balance, is as close to the detector array as possible. Two rocking solenoids are used which actuated in synchronism with the azimuth scan mirror. To transform the rocking motion from a horizontal plane to a vertical plane, a transfer arm (bell crank) is used. The calculated wobble angle is $\pm 4.0°$ using a 0.020 inch thick silicon plate.

Some obscuration will occur during the extreme right azimuth scan angle. However, the amount is very small and deemed acceptable to system performance. A preliminary investigation indicates the magnitude of the obscuration to be equal to or less than 5 percent.

7.3.5 RECOMMENDATIONS

Most image improvement techniques discussed in paragraphs 7.3.1 through 7.3.3 have been successfully implemented in two imaging systems, the VANS and the TE cooled extended range version of the AN/TAS-3. A substantial degree of improvement has been achieved in reduced raster flicker, grey scale rendition and display homogenity as well as improved MRT and MTF. These improvements have been realized without a major redesign effort and are readily adaptable to present AN/TAS-3 hardware.

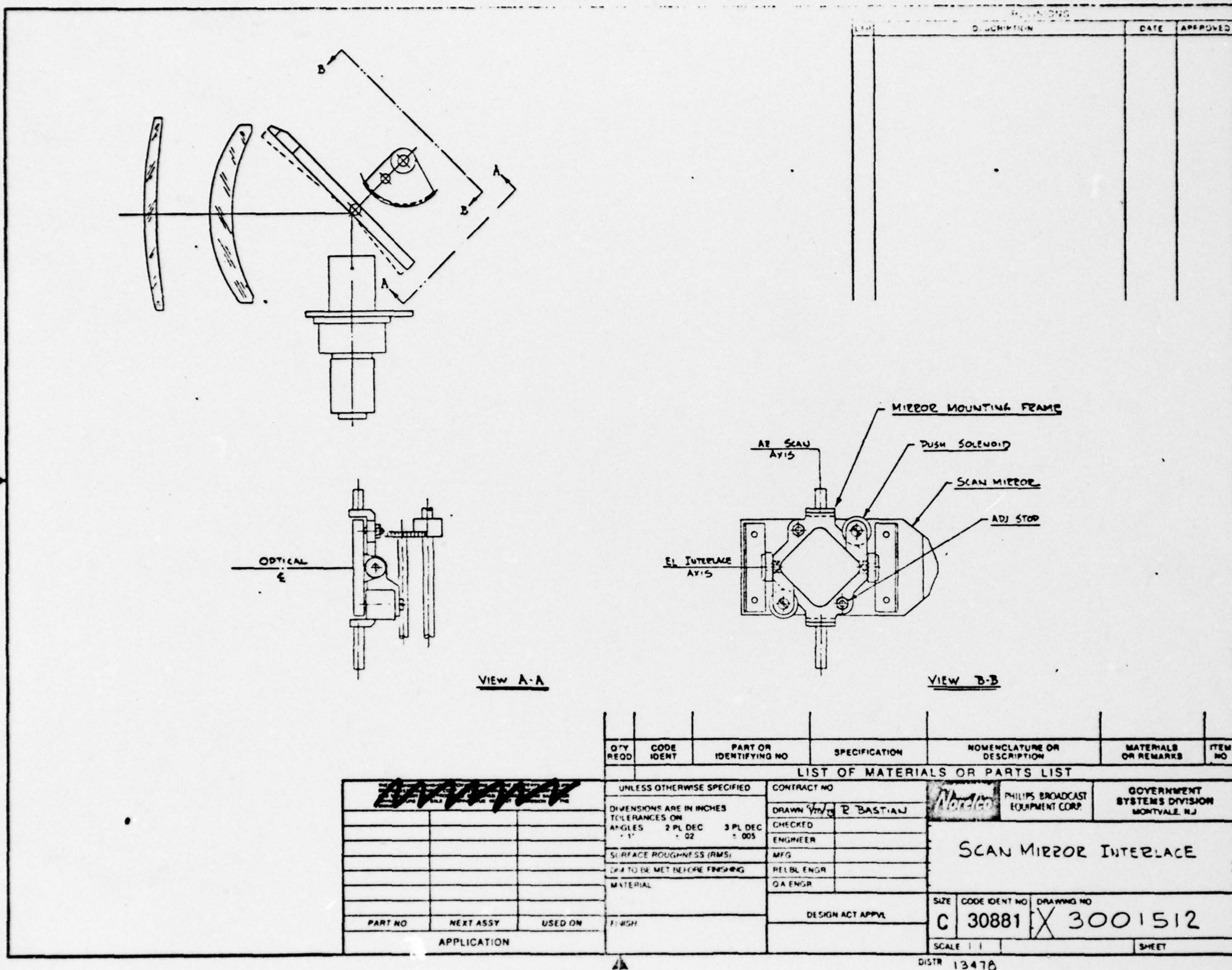
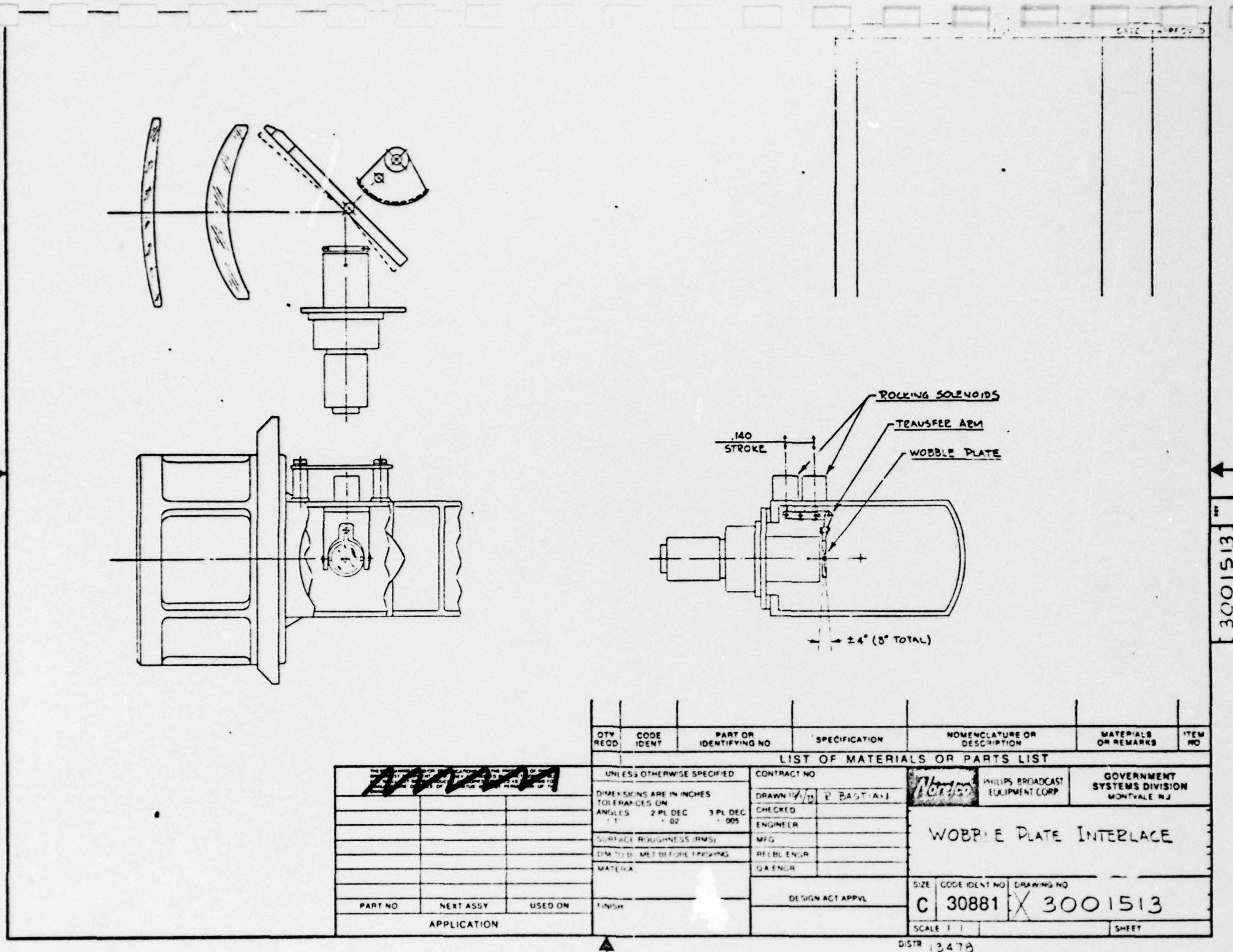

REVISIONS
DESCRIPTION
DATE
APPROVED
MIRROR MOUNTING FRAME
PUSH SOLENOID
SCAN MIRROR
ADJ STOP
AZ SCAN AXIS
EL INTERLACE AXIS
OPTICAL ℄
VIEW A-A
VIEW B-B
Q'TY REQD
CODE IDENT
PART OR IDENTIFYING NO
SPECIFICATION
NOMENCLATURE OR DESCRIPTION
MATERIALS OR REMARKS
ITEM NO
LIST OF MATERIALS OR PARTS LIST
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
ANGLES ± 1°
2 PL DEC ± .02
3 PL DEC ± .005
SURFACE ROUGHNESS (RMS)
MATERIAL
FINISH
CONTRACT NO
DRAWN R BASTIAN
CHECKED
ENGINEER
MFG
RELBL ENGR
QA ENGR
DESIGN ACT APPVL
PHILIPS BROADCAST EQUIPMENT CORP.
GOVERNMENT SYSTEMS DIVISION MONTVALE, NJ
SCAN MIRROR INTERLACE
SIZE C
CODE IDENT NO 30881
DRAWING NO X 3001512
SCALE 1:1
SHEET
PART NO
NEXT ASSY
USED ON
APPLICATION
DISTR 13478
3001512

Figure 7-3


ROCKING SOLENOIDS
TRANSFER ARM
WOBBLE PLATE
.140 STROKE
±4° (8° TOTAL)
3001513
QTY REQD
CODE IDENT
PART OR IDENTIFYING NO
SPECIFICATION
NOMENCLATURE OR DESCRIPTION
MATERIALS OR REMARKS
ITEM NO
LIST OF MATERIALS OR PARTS LIST
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
ANGLES
2 PL DEC
3 PL DEC
.005
SURFACE ROUGHNESS (RMS)
MATERIAL
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CONTRACT NO
DRAWN
R. BASTIAN
CHECKED
ENGINEER
MFG
RELBL ENGR
QA ENGR
DESIGN ACT APPVL
Norelco
PHILIPS BROADCAST EQUIPMENT CORP
GOVERNMENT SYSTEMS DIVISION
MONTVALE NJ
WOBBLE PLATE INTERLACE
SIZE
C
CODE IDENT NO
30881
DRAWING NO
X 3001513
SCALE 1:1
SHEET
DISTR 13478
PART NO
NEXT ASSY
USED ON
APPLICATION

Figure 7-4

It is therefore recommended that, as a minimum, future versions of the AN/TAS-3 incorporate the specific modifications listed below.

a. Overload recovery circuit modification
b. Preamplifier gain reduction
c. Preamplifier bandwidth increase (Hi-f cutoff)
d. High Frequency Compensation (further study required)
e. New type multiplexer with reduced switching spikes
f. Increase in multiplexer switching rate (master clock)
g. Removal of interchannel blanking
h. Increase frame rate to at least 30 fps
i. Replace transistor shunt with FET shunt
j. Change CRT phosphor (further study required)
k. Evaluate signal processing techniques from Common Module Program.

Quasi-interlace, as discussed in paragraph 7.3.4, would provide a more uniform display raster and also improve the vertical MTF. However, the methods of achieving the interlace have not been mechanically or electrically implemented and the affect on system weight and power consumption evaluated. Further study of quasi-interlace is required.

7.4 EXTENDED RANGE OPTICS

Based on PAVSC observations of many missile firings, discussions with DRAGON gunners and a review of a compilation of most missile firings to date utilizing the NVS, it appears that the optimum firing range for the DRAGON system guided by the AN/TAS-3 against a tank size target is about 750 meters. The resolution and sensitivity of the NVS is sufficient to afford the gunner a good sight picture of a tank size target under most field conditions at this range.

At 750 meters the gunner has about 8 seconds for his sight picture to clear from launch blast and afterburn, to recover from launch shock and to re-establish a smooth track and/or stable aim point.

TOW firings during OT II test phase at Hehenfels, Germany, have resulted in a 60 percent hit capability from 600 to 1000 meters using the NVS as compared to a 17 percent hit record using the day tracker under illumination. An unexpected result was a 75 percent hit record at 1500 to 1675 meters with TOW.

PAVSC recommends that the NVS be outfitted with a somewhat larger objective lens 4.9", f/1.2, to give the DRAGON weapon, guided by the NVS, an optimum hit range of 1000 meters, the maximum wire length of the DRAGON missile. The extended range NVS would also make the NVS very effective for the TOW missile system giving the weapon a good hit probability in the 1600 to 2000 meter range, and providing a good survivability range against threat force night counterfire, such as that from 50 caliber weapons.

A comparison of the parameters of the AN/TAS-3 and a modified system incorporating an extended range lens to give the DRAGON system an optimum range of 1,000 meters is presented in Figure 7-5. Thermoelectric cooling parameters are included.

PARAMETER	AN/TAS-3	FULL DRAGON RANGE NVS
f#	1.2	1.2
f_L	3.6"	4.9"
Lens Dia	3.0"	4.08"
DAS (mr)	0.86	0.63
NETD °C	0.14	0.14
FOV	4° x 6°	2.9° x 4.4°
Frame Rate/Sec	15	30
Detector		
Type	PbSe	PbSe
Number	64	64
Oper. Temp	145°K	195°K
Cooler Type	Joule-Thompson	Thermoelectric
Weight (lbs)	10.3	11.5 est.
Battery Capacity (AH)	1	3.6
Cont. Oper. Time (Hr)	1	1.8
5 Min ON, 5 Min OFF cycles	6	21
Display		
Type	CRT	CRT
Magnification	4.8	6.5
Logistics	Battery Freon 14 Gas Bottle Charging Station	Battery

Figure 7-5. System Parameters

7.5 RECOMMENDATIONS FOR TOW

During the ED phase of the AN/TAS-3 program several adaptations of the Night Vision Sight (NVS) were made for the TOW weapon, Figures 7-6 through 7-10. They are:

Sight	Cooling	Lens	Contract
TE/NVS	TE	7.2" FL, f/1.2	DAAK02-72-C-0483
ER/NVS	JT	7.2" FL, f/1.2	DAAK02-73-C-0022
AN/TAS-3 w/TOW Bkt	JT	3.6" FL, f/1.2	DAAK02-72-C-0156

These programs demonstrated a number of significant features of the basic AN/TAS-3 design, as follows:

- Commonality of modules
- Adaptability for conversion to TE cooling
- Adaptability for conversion to a dedicated TOW configuration
- Capability of performance with the TOW weapon.

Commonality of Modules DRAGON/TOW - The inherent design configuration of AN/TAS-3 will permit the complete scanner assembly to be interchangeable between a TOW and DRAGON system. This is true for a JT or TE final configuration.

Conversion of TE Cooling - Completion of the TE-DNVS demonstrated that the existing AN/TAS-3 JT design can readily be converted to TE cooling with relatively minor changes. These are: removal of the cryogenic cooling system, replacement of the Detector/Bias Assembly, modification of the detector mounting surface, modification of main frame battery bracket and replacement of the battery. All electronic components, with the exception of the detector and battery remain identical. Refer to Figures 7-7 and 7-9.

TOW Configuration - A dedicated TOW configuration of the NVS is illustrated in Figures 7-6 and 7-7. This JT cooled unit includes an integral boresighting mechanism which attaches to the TOW weapon and incorporates a 7.2" focal length lens. The entire scanner assembly of this unit is identical to the AN/TAS-3. In a TE cooled unit, the outer housing will be substantially simplified by elimination of the tube portion of the housing required for the gas bottle and valve.

TOW Firings - TOW firings during OT II tests in Germany, April 1974, showed the effectiveness (56.2% hits) of the AN/TAS-3 when used with TOW. It is expected that hit percentage would have improved had not berm obscuration and gunner attitude been questionable factors as indicated in the PAVSC field test report. Furthermore, it is anticipated that if the full DRAGON range optics recommended in paragraph 7.4, or the TOW dedicated extended range optics is adopted, performances will be substantially improved.

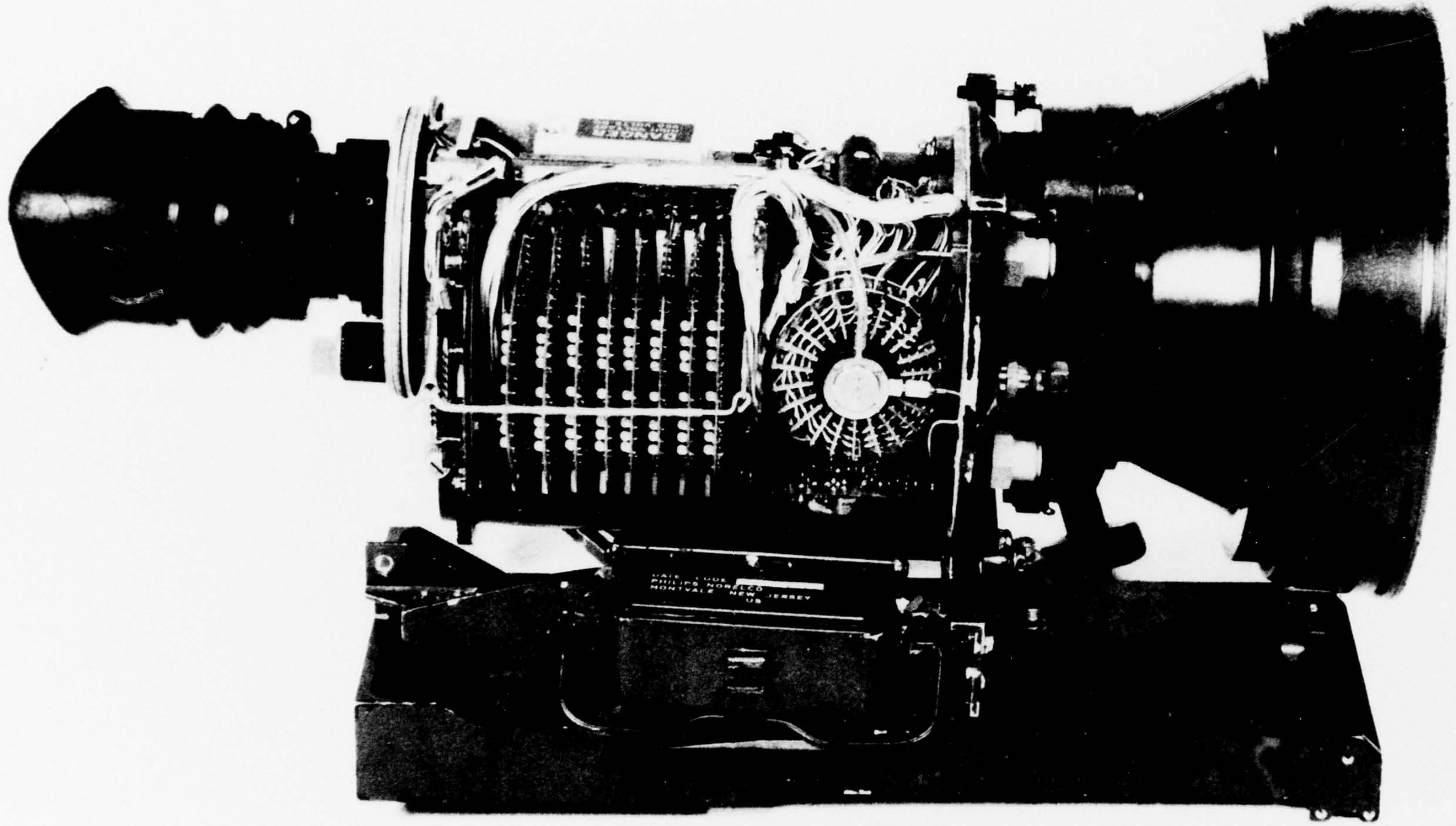


Figure 7-6. ER/NVS - J-T Cooled - TOW Configuration

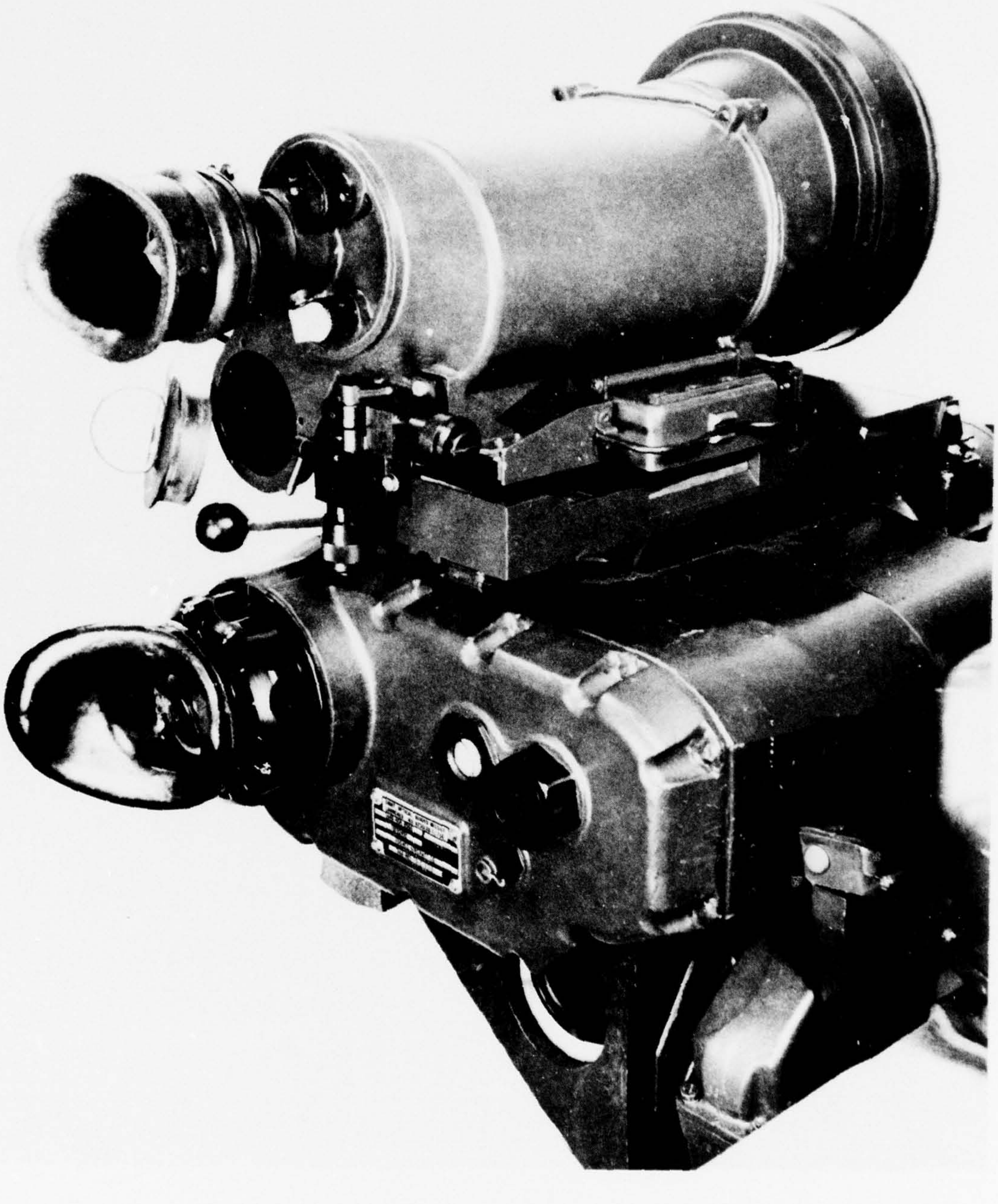


Figure 7-7. ER/NVS - J-T Cooled - TOW Configuration

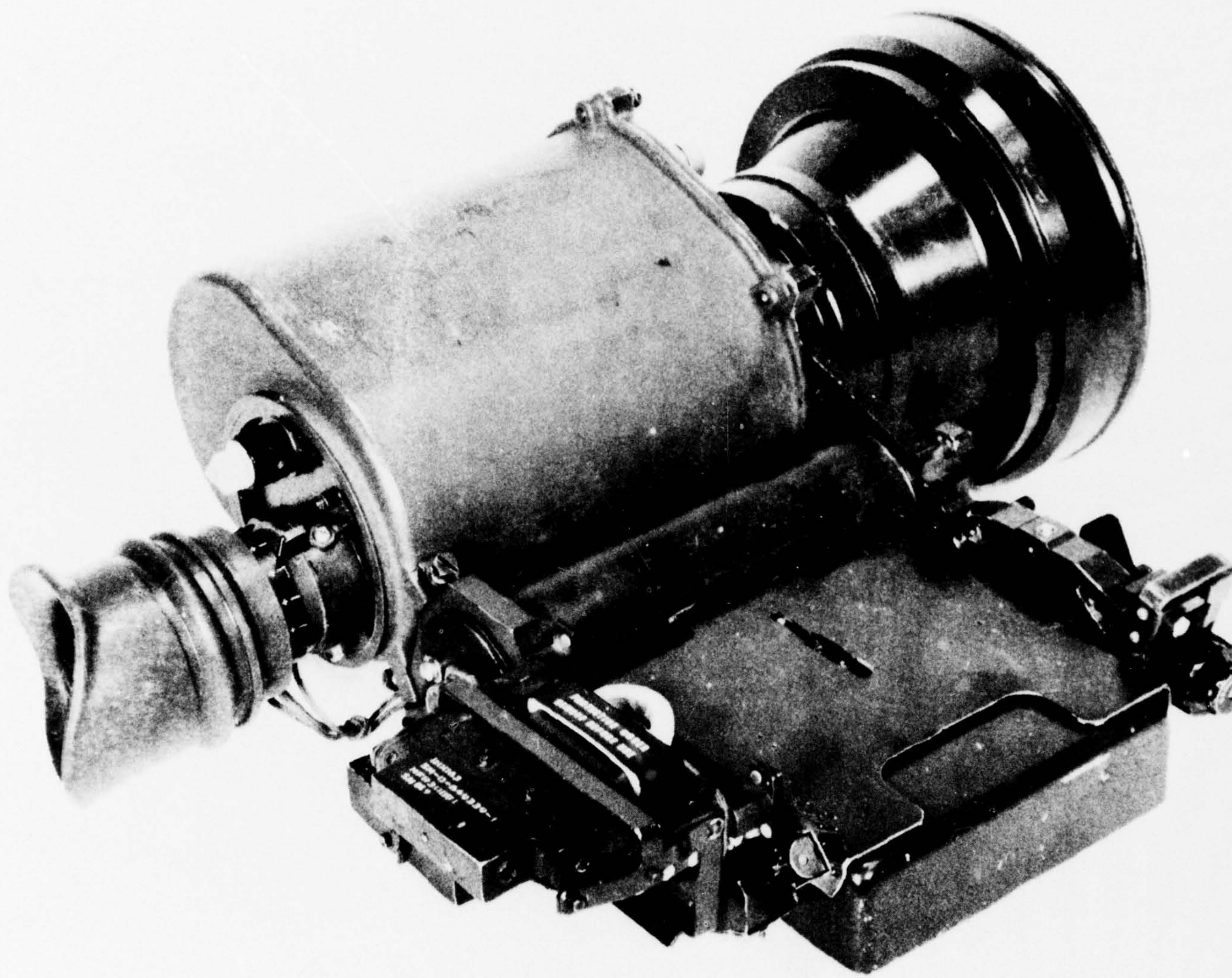


Figure 7-8. TE/NVS - TE Cooled - DRAGON/TOW Configuration

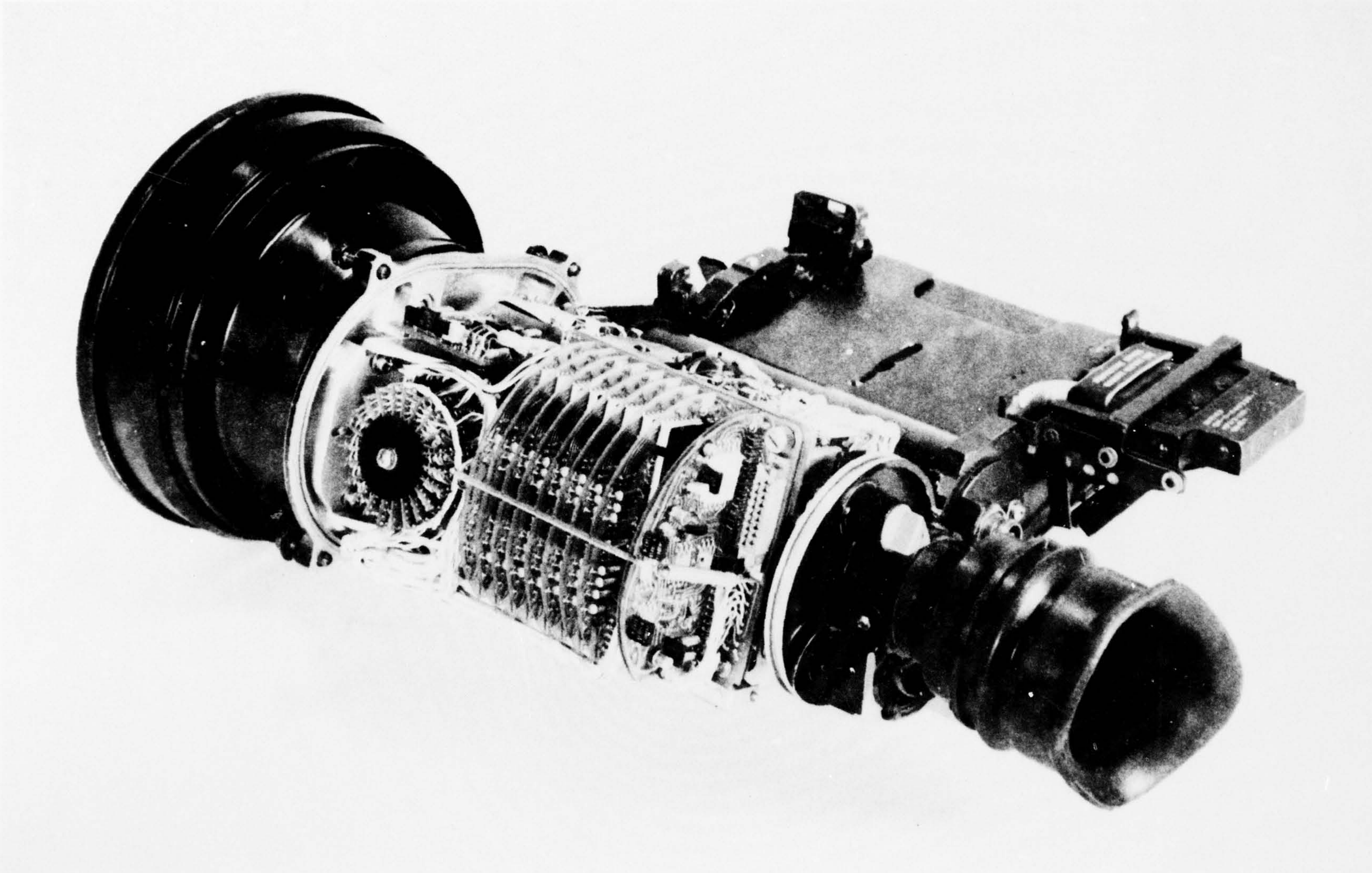


Figure 7-9. TE/NVS - TE Cooled - DRAGON/TOW Configuration

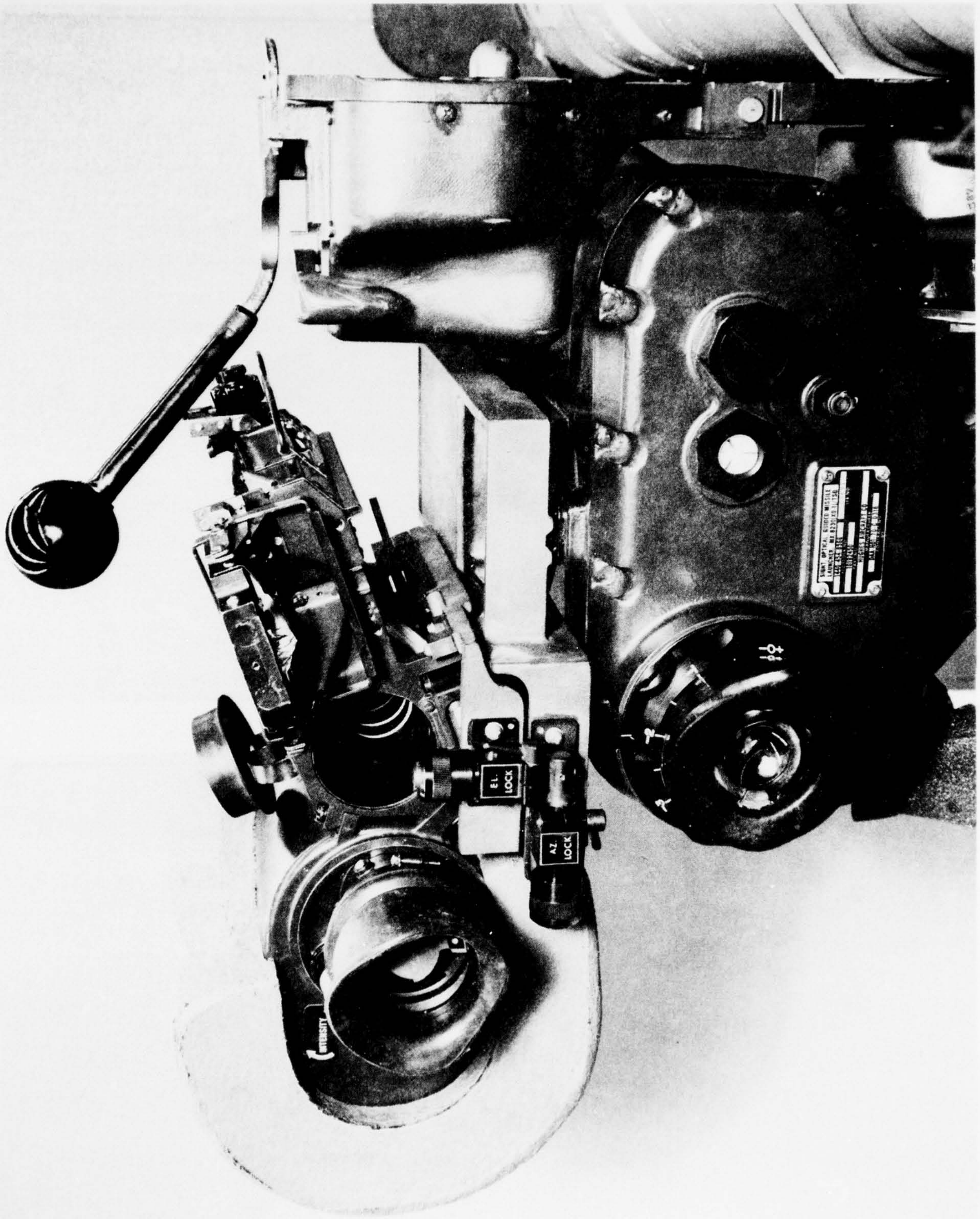


Figure 7-10. AN/TAS-3 with TOW Bracket

Based on the preceding factors, PAVSC recommends that, as a minimum, the AN/TAS-3 be considered as an interim night sight for TOW. It is further recommended that to improve performance, minimize logistics and to optimize human factors considerations for the gunner that a dedicated night sight for TOW be configured with extended range optics (4.9" FL, f/1.2), TE cooling and a housing dedicated for the TOW weapon.

7.6 RECOMMENDATION FOR EXISTING AN/TAS-3 NVS

At this time there are 29 ED and 4 APE models of the AN/TAS-3 in existence. PAVSC believes there is a need to have all AN/TAS-3 units available on a standby basis. Standby systems will provide an immediate NVS capability at minimum cost and provide maximum utilization of the large expenditure of time and Government funds that have been invested in the existing system.

Modifications and improvements determined during field testing which are included in the APE units, have not been incorporated into all 29 ED systems. Therefore, PAVSC recommends that all ED models be updated, as reuired, to include the following items:

- Improved Boresight Modification
- Refurbishment to eliminate degraded detectors
- Addition of Freon dryer/filter
- Modification to accept ruggedized BVD
- Replacement of eyeshields
- Addition of noise suppressor valve
- Replacement of soft rubber battery connectors

It is also recommended that the following APE improvements be included:

- Low Voltage Power Supply
- High Voltage Power Supply
- Scanner Printed Circuit Assembly

The preceding modifications will provide a source of immediate night sight capability with JT cooling. It has, however, long been PAVSC's contention that man portable type Night Vision systems should employ TE instead of JT-type cooling to enhance "Designated Gunner" and operation and minimize logistics problems and life cycle costs (refer to paragraph 7.2). It is, therefore, strongly recommended that, in addition to the modifications, all or a portion of the 29 units be converted to TE cooling and modified to incorporated a 4.9 inch focal length full DRAGON range lens. It has been demonstrated on Contract DAAK02-72-C-0483 and by in-house effort that this TE conversion can readily be accomplished.

7.7 BATTERY CHARGER RECOMMENDATIONS

During field testing of the DRAGON Night Sight reports were received of degraded battery performance, that is, discharge time under field operation averaged somewhat less than the normal 60 minutes. This led to comparison test between the Battery Charger Adapter, NVL847 (schematic SC-D-770955) which was being used in field tests, and a battery charging circuit in use at PAVSC.

The PAVSC charging circuit is shown schematically in Figure 7-11. Two DRAGON batteries SM-D-770180 containing Gulton 5R125 cells, SM-A-770338, were used for the test.

Results of the test are plotted in Figure 7-12 and tabulated in Figure 7-13. As shown, there is a vast improvement in battery performance when using the PAVSC charging circuit. It is to be noted that in the last charging cycle (cycle 19) the batteries were interchanged on the charges. As shown, the resulting discharge times were comparable to those previously obtained. This further confirms the relationship between charging methods and discharge time.

The most significant feature of the PAVSC design is considered to be the preconditioning cycle which automatically discharges the DRAGON battery mode. Additionally, in the charging mode, the charging current is controlled and tapered. Control of the current is maintained by sensing the battery terminal voltage. This combination of characteristics in the PAVSC charger eliminates the possibility of battery polarity reversal and thermal runaway. These conditions are considered to be principle causes of reduced battery performance when charged in the NVL847 charger.

Therefore, it is recommended that a battery charger suitable for field use be developed using the PAVSC circuit. Additionally, the charger should be capable of operation from 50, 60, 400 cycles and vehicle battery power.

The preceding test results and recommendations were documented in a report to NVL dated 28 February 1975, GSDR No. 793.

7.8 LAUNCH BLAST SIMULATOR RECOMMENDATIONS

In a 60-day program, under modification P00018 to the ED contract, PAVSC developed an experimental model of a Launch Blast Simulator (LBS). Results of

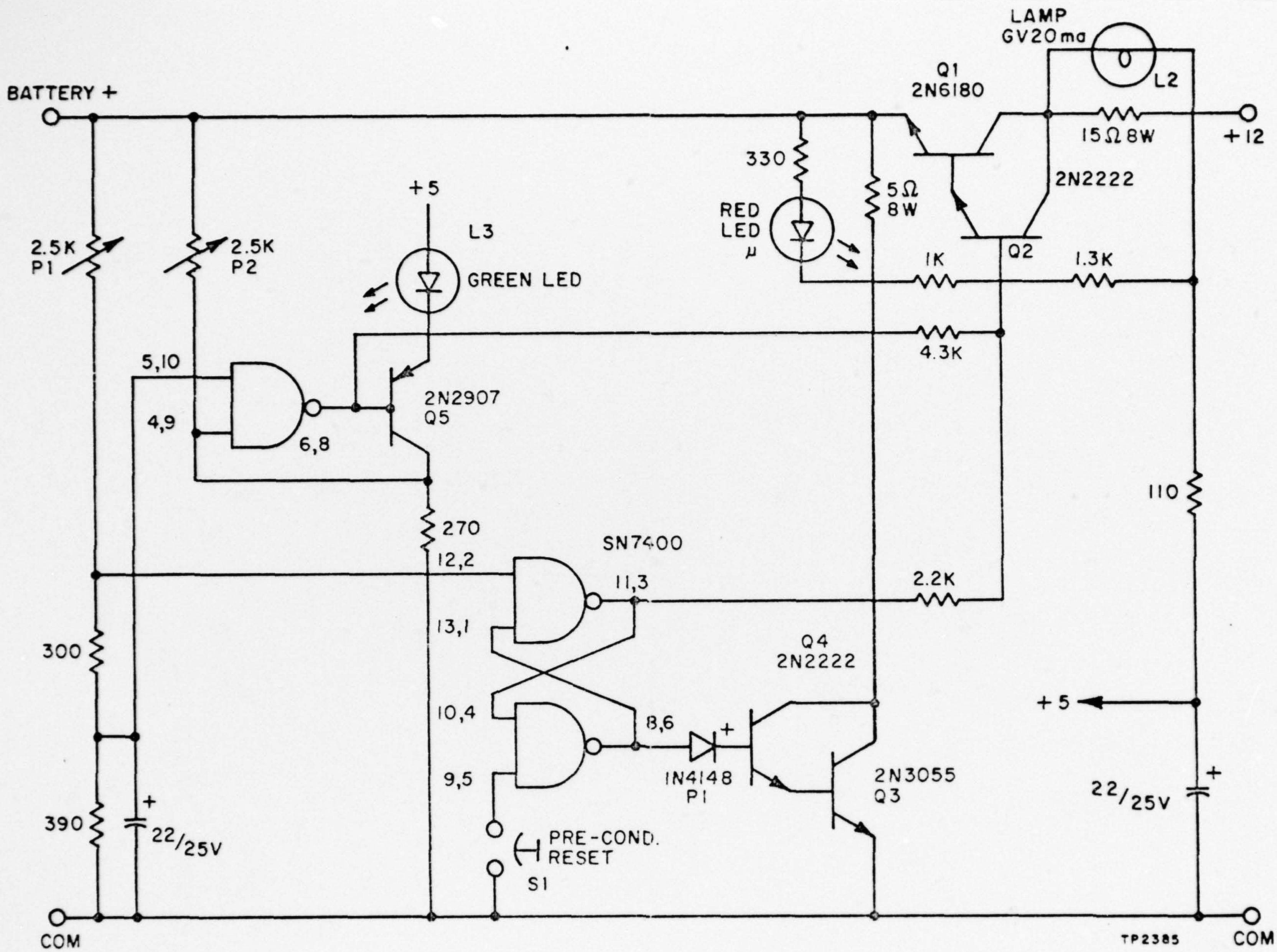
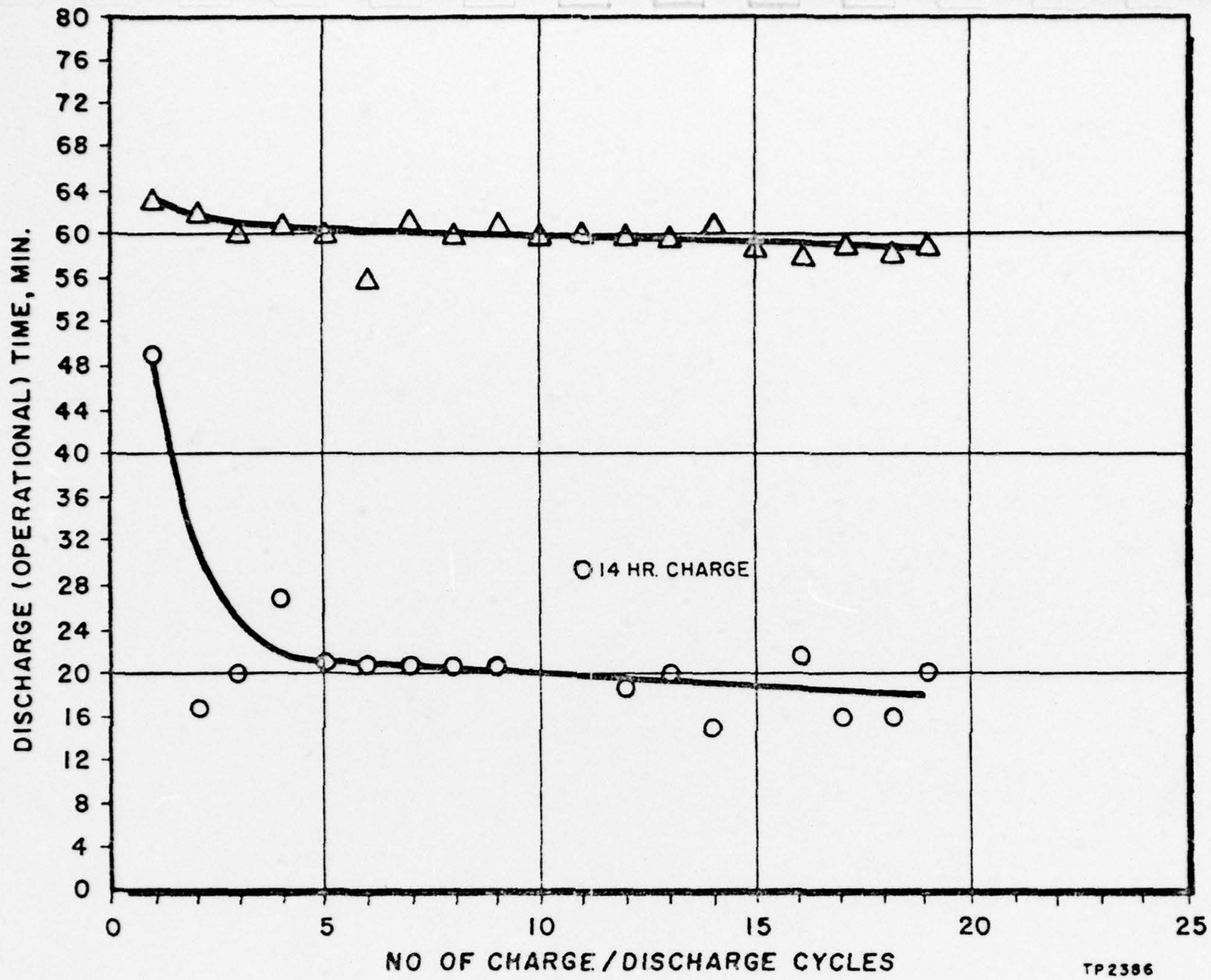


Figure 7-11. Philips Battery Charging Circuit with Preconditioning Circuit



LEGEND:

△ PHILIPS CHARGER

○ NVL 847 CHARGER

TEST BATTERIES — SM-D-770180 WITH GULTON 5R125 CELLS (SM-A-770338)

AVG. CHARGE TIME — 6 HOURS

DISCHARGE LOAD — 6 OHMS

DISCHARGE CUTOFF — 5.78 VOLTS (APPROX.)

CHARGE CONDITION — ROOM AMBIENT (70° F NOMINAL)

Figure 7-12

COMPARISON DATA - PHILIPS BATTERY CHARGER VS. NVL847 BATTERY CHARGER

DATE	CYCLE	CHARGE TIME NVL847	CHARGE TIME PHILIPS (1)	DISCHARGE/OPERATIONAL TIME MINUTES (2) NVL	DISCHARGE/OPERATIONAL TIME MINUTES (2) PBEC
10/2	1	Not Recorded	Not Recorded	49	63
10/3	2	10 hr	10 hr	17	62
10/4	3	6 hr 40 min	6 hr 5 min	20	60
10/7	4	9 hr 30 min	9 hr 25 min	27	61
10/8	5	7 hr 20 min	7 hr 16 min	21	60
10/10	6	8 hr 50 min	8 hr 50 min	21	56
10/10	7	7 hr 5 min	6 hr 28 min	21	62
10/11	8	8 hr 1 min	6 hr 2 min	21	60
10/14	9	8 hr 25 min	7 hr 7 min	21	61
10/15	10	Chg cont'd next day	5 hr 43 min	-	60
10/16	11	14 hr 29 min	5 hr 38 min	30	60
10/17	12	6 hr 2 min	5 hr 30 min	18	60
10/18	13	5 hr 51 min	5 hr 48 min	20	60
10/21	14	5 hr 41 min	5 hr 36 min	15	61
10/22	15	Chg. cont'd next day	5 hr 43 min	-	59
10/23	16	8 hr 55 min	5 hr 41 min	22	58
10/24	17	6 hr 3 min	5 hr 53 min	16	59
10/25	18	5 hr 45 min	5 hr 41 min	16	58
10/[illegible] (3)	19	7 hr	6 hr 55 min	20	59

(1) All Philips Charging Times include preconditioning time of approximately 25 min.

(2) Discharged to approximately 5.78V each discharge cycle.

(3) On this charge cycle batteries were interchanged on chargers.

Figure 7-13

this effort are fully described in a final report dated 2 August 1973, PAVSC GSDR No. 565. The LBS was designed as a simulator to produce an effect of the Night Vision Sight display similar to that produced by the initial missile blast and ensuing afterburn.

In an Army feasibility test final report dated March 20, 1974, six of eight test soldiers stated that the LBS simulator training "would benefit a Night Sight gunner". In the same report, the U.S. Army Infantry Board, in part, concluded that "An obscuration device for use with the DRAGON Training Equipment and Night Sight to train gunners is desirable and feasible".

During and after gunner training conducted by both PAVSC and the Army, PAVSC observed 'first round" firings by student gunners. These observations showed that first round hits were 52 percent greater by gunners trained using the LBS then by gunners trained without use of the LBS. First round firings observed are listed below.

With LBS Training

Hits	Firings	% Hits
19	30	63.3

Without LBS Training

Hits	Firings	% Hits
9	12	41.6

Based on the Army report and the available PAVSC data, it is recommended that a launch blast simulator be included in any future NVS training. Use of the LBS should substantially reduce training costs associated with live firings. It is also recommended that the existing experimental PAVSC LBS design be improved and ruggedized to make available a unit suitable for field training applications.

7.9 CARRYING BAG RECOMMENDATION

There have been numerous suggestions during the course of the DRAGON program for modifications to the Night Vision Sight (NVS) carrying bag that would improve its utility in the field. Among the most important was a recommentation that the carrier be changed to a back pack configuration, with, or without, the use of a back pack frame.

In a technical proposal dated 23 May 1974, PAVSC/GSDR No. 712, PAVSC recommended that the existing NVS carrying bag design be modified for use with the standard Army All-Purpose Lightweight Individual Carrying Equipment Sys-

tem (ALICE). It was also recommended that a supplementary carrier be designed to transport sufficient batteries and coolant bottles to support ten hours of continuous operation. The proposed concept is illustrated in Figure 7-14. It is to be noted that in the event TE cooling is implemented, the concept can readily be modified to eliminate storage for the coolant bottles.

The present NVS carrying bag can be easily modified for use with the ALICE system of hardware by the addition of the standard design attaching envelope to the surface of the bag. The back pack can also be used without the frame by attaching the standard shoulder straps directly to metal loops and rings fastened to the bag. A shortened version of the present carrying strap will remain for use when the night sight must be hand carried.

The design for the supplementary carrier for battery and coolant bottles is illustrated in Figure 7-15. The basic component in the construction of this carrier is a simple molding of closed cell polyethylene foam, the same material that is used for the night sight and tracker shock cushions. This molding will be approximately 3-1/2 inches wide by 7 inches high x 7 inches deep, and will have three cavities for the support of two batteries and one bottle or the equivalent of two hours of system operation. Side by side attachment of up to five of these modules, as shown, will give the required ten hours of operation in a package 17 inches long by 7 inches high by 5 inches deep. A further amplification of this concept might include the addition of the Boresight Verification Device to the package.

PAVSC recommends that this concept be given consideration in any future effort concerning the DRAGON Night Vision Sight.

7.10 IMPROVED BORESIGHT VERIFICATION DEVICE

In February 1973, PAVSC completed the design and fabrication of the first three experimental models of a Boresight Verification Device (BVD) to be used during testing and evaluation of the Night Vision Sight (NVS). These experimental BVD's established the feasibility of using a lightweight collimating device to enable field boresighting between the NVS and the tracker, in lieu of a distant aiming point. A distant aiming point necessitates finding or setting up of a common IR and visible radiation source which is remote from the DRAGON gunner. The experimental BVD is shown in Figure 7-16. Although the experimental BVD's performed their intended function, they lacked the ruggedness and ease of operation required for military field use.

In March 1974, PAVSC proposed a program to NVL to ruggedize the BVD and modify its design to simplify field operation and installation. Authorization to proceed with this program was given in June 1974, at which time PAVSC began the redesign effort. Fabrication and alignment of the Ruggedized Boresight Verification Devices (R-BVD) was completed in February 1975 and environmental tests were successfully completed in March. Figures 7-17 and 7-18 show the R-BVD.

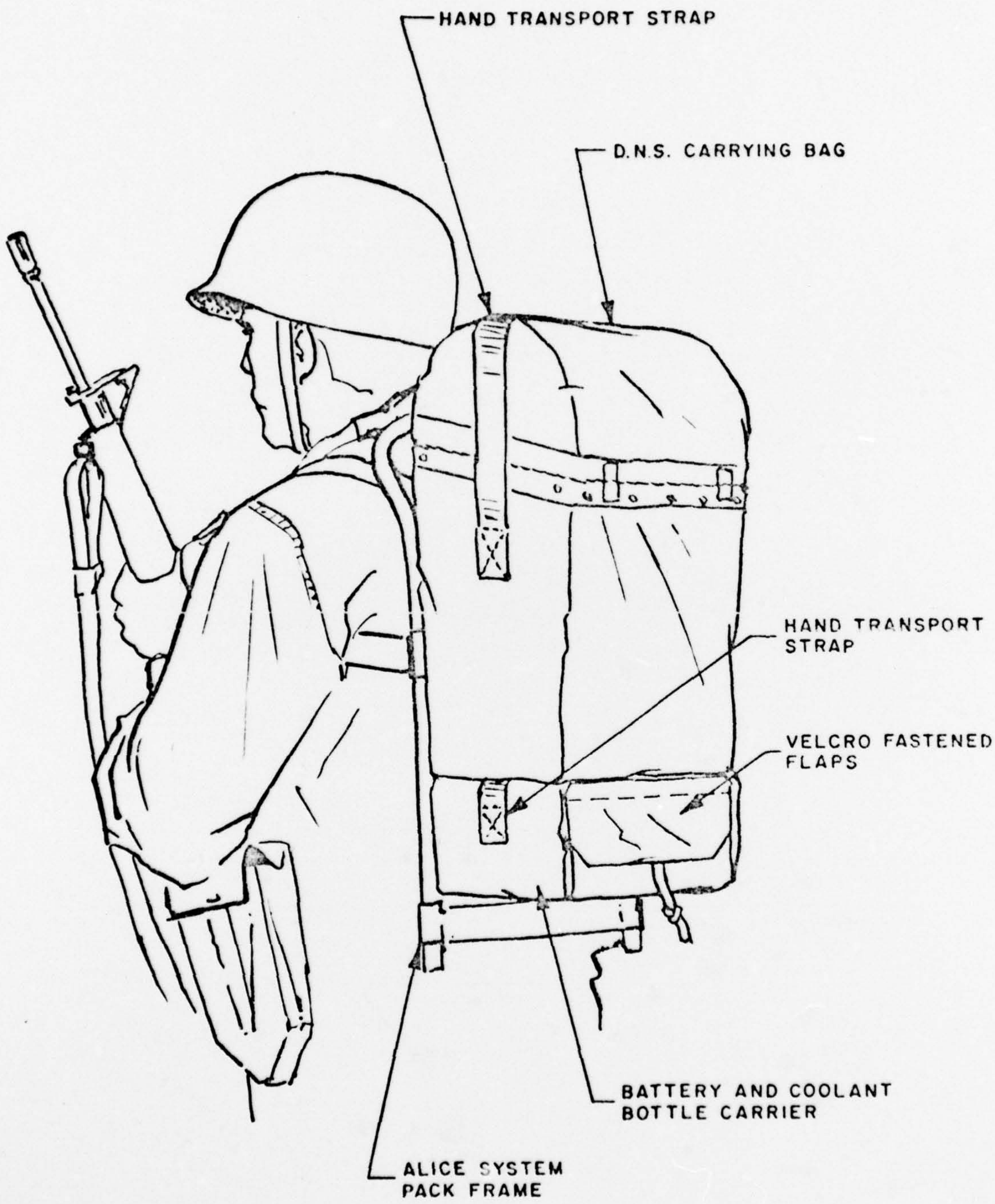


Figure 7-14. "ALICE" Carrying Bag

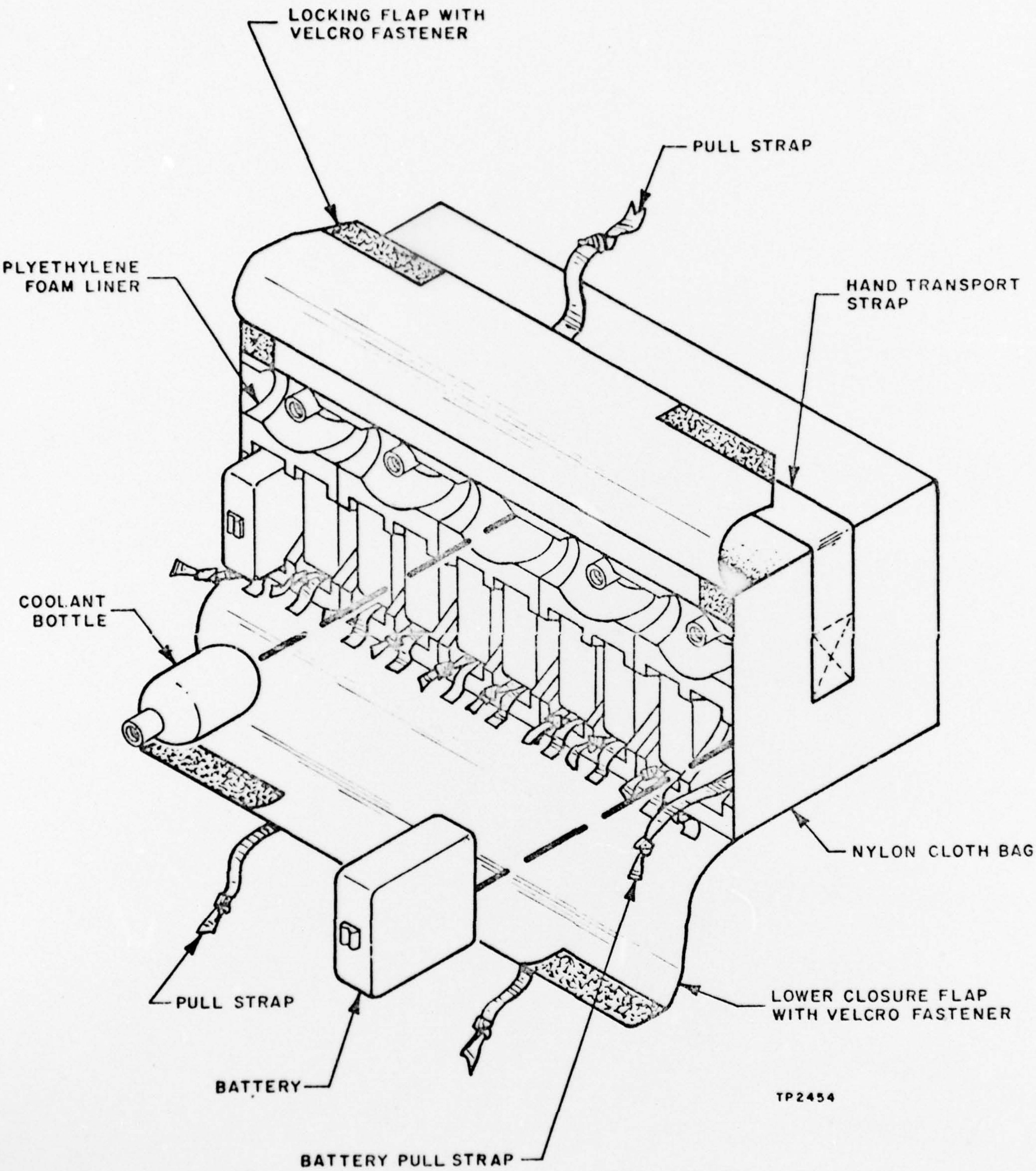


Figure 7-15. Internal View - "ALICE" Carrying Bag

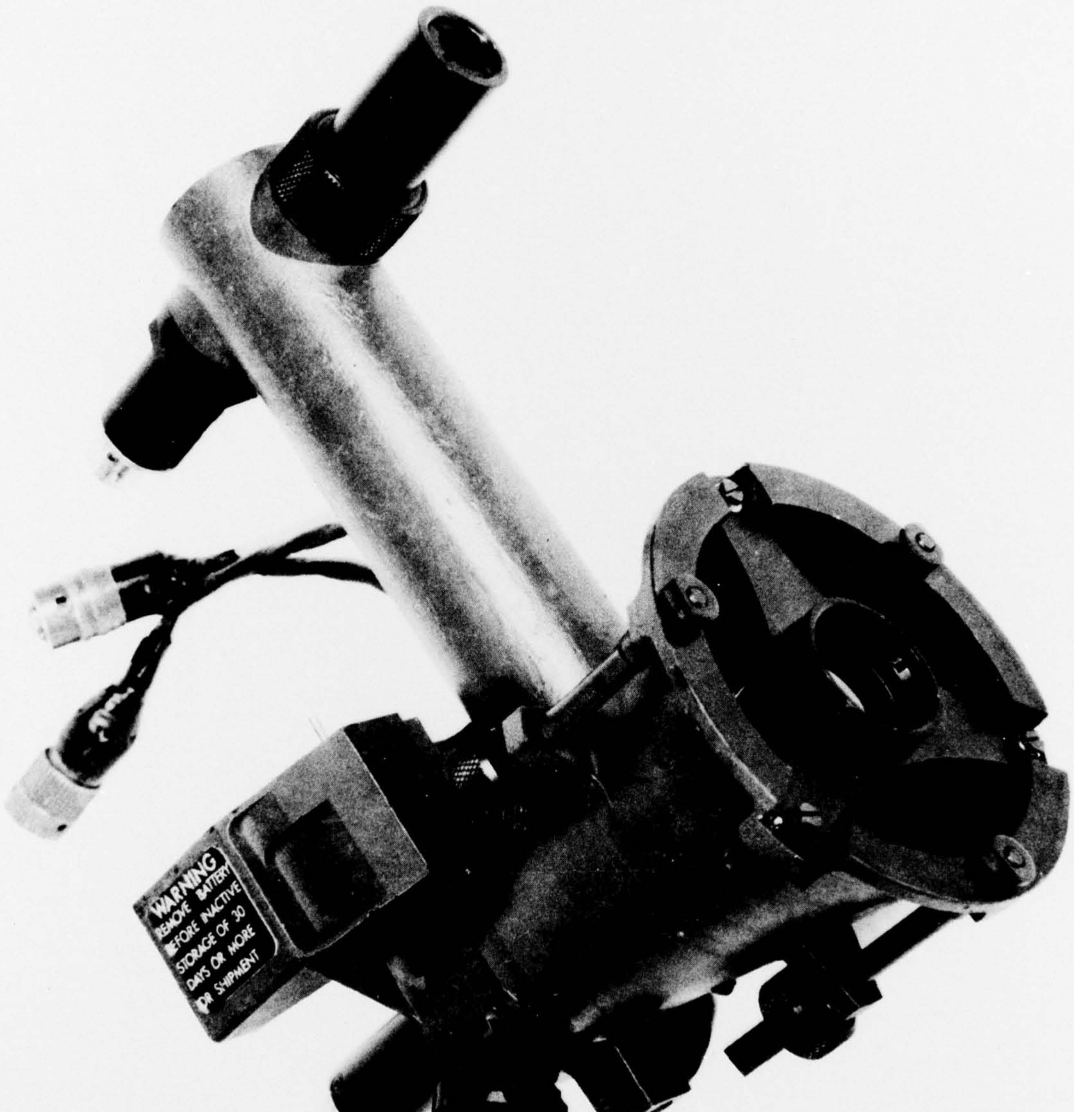


Figure 7-16. Boresight Verification Device - Experimental Model

Figure 7-17. Boresight Verification Device - Ruggedized Model

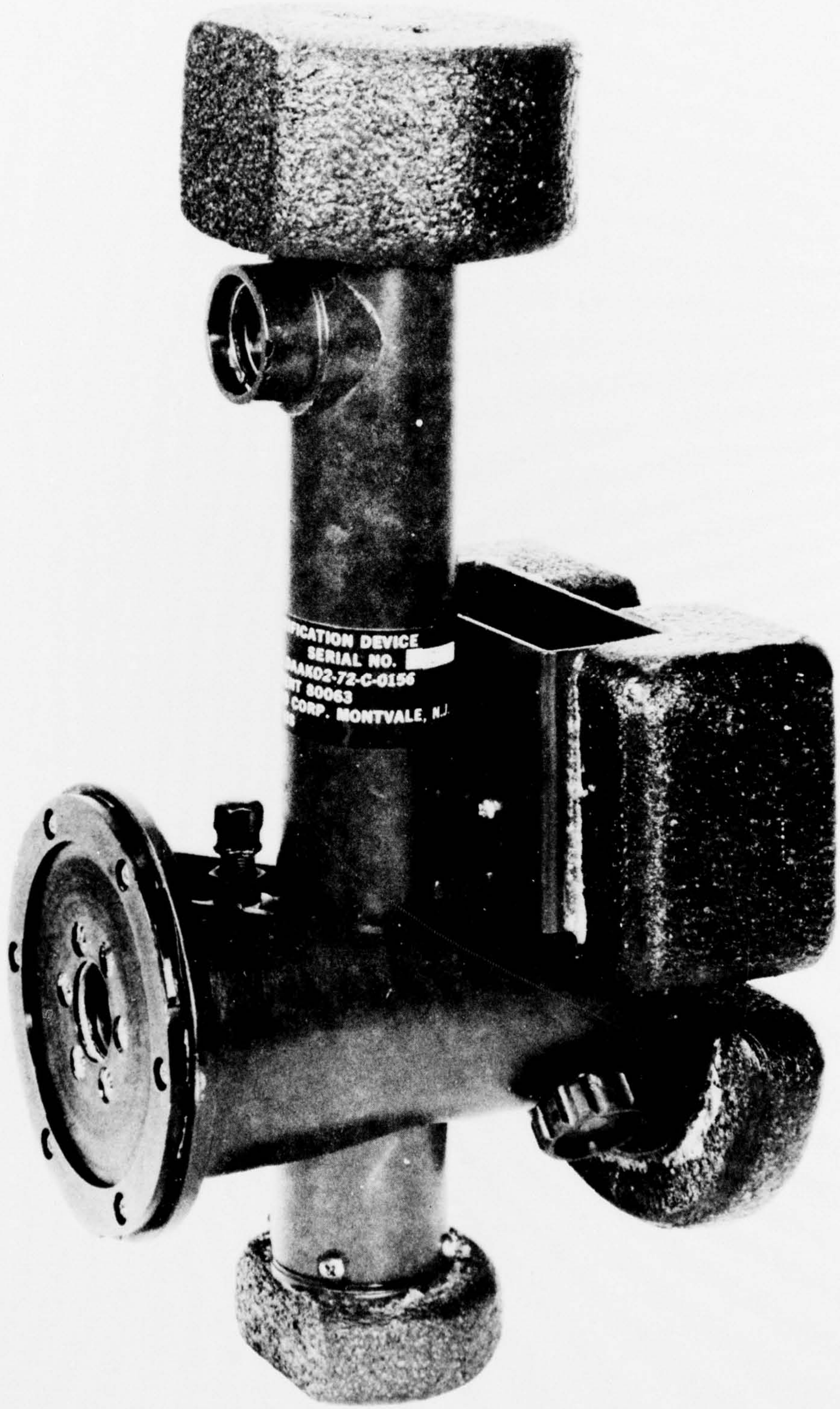


Figure 7-18. Boresight Verification Device - Ruggedized Model

All of the known shortcomings of the experimental models were corrected in the R-BVD. Improvements included:

- Simplified attachment to the NVS and elimination of the weak attaching latches.
- Increased brightness of the visible target image.
- Improved design to withstand field handling.
- Elimination of exposed cables.
- Simplified machining of parts.
- Simplified internal optical alignment and test.

A review of the completed R-BVD design has indicated that a weight saving in the order of 0.1 to 0.2 pound can be realized in future units by reducing some thick steel sections in the inner optical assembly. Actual weight of the present unit is 2.95 pounds excluding the battery weight of approximately 0.76 pound. In addition an improvement in the visible images of the R-BVD can be made to facilitate laboratory tests of the units. The present visible images are satisfactory when the R-BVD is installed in a combined Tracker-NVS. It is recommended that these additional improvements be incorporated in any future production units.

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